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CORRECTION

MONTHLY WEATHER REVIEW, July, 1926:

Table of contents, first column, thirteenth line, "W. P. Stuart," should be "W. P. Stewart"; also on page 298, near bottom of first column.

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THE VERTICAL DISTRIBUTION OF ATMOSPHERIC EDDY ENERGY

By CARL-GUSTAF ROSSBY, United States Weather Bureau, August, 1926

(This paper presents a portion of the results of investigations carried on by the author as a fellow of the American-Scandinavian Foundation for 1926)

INTRODUCTION

In this paper an attempt is made to study theoretically the vertical variation of atmospheric eddy viscosity (c_M) and its relations to the distribution of temperature and wind with height. An investigation of this kind seems desirable for several reasons. The observed values of C_M vary between such wide limits that it hardly is possible to say what the individual observations really represent.[1] A rational grouping and interpretation of these empirical data can not be accomplished until theoretical considerations have given an indication as to the connection between c_M and the chief factors which regulate the production and consumption of atmospheric eddies, viz, the vertical stability of the stratification and the rate of sheering between superposed layers of different horizontal velocity.

Recently a few systematic attempts have been made to calculate the vertical distribution of c_M from observations of the variation of wind with height, the horizontal barometric gradient being known (*1*). The curves thus obtained show certain characteristic features, which likewise seem to require a theoretical explanation.

The author has already on an earlier occasion (*2*) tried to show how a solution of the problem above formulated could be approached; continued study of it seemed however to indicate that the method then used would not be adequate to the purpose and it was abandoned. The chief aid in the paper here presented was obtained by adapting a certain theorem in an important paper by L. F. Richardson (*3*), giving an extension and application of Reynold's Criterion of Turbulence to atmospheric systems. This theorem has the form of an integral equation, expressing the rate of increase of the total energy within a vertical air column as the sum of the rates of inflow of eddies through the boundaries and production of eddies within the system. Richardson's theorem is here applied to air columns of infinitesimal height and thus changed into a differential equation. In performing this transformation it was necessary to make a hypothesis concerning the vertical transport of eddy energy. The one here made is that it follows the same law as the vertical transport of heat and momentum, in accordance with a suggestion made by Richardson (*3*).

I. THE FUNDAMENTAL EQUATION

Let x, y, and h be the three orthogonal coordinates (h the height above ground); let E' be the total turbulent energy within the atmospheric volume V and u and v the two horizontal mean wind components in the direction of x and y, respectively. Then the rate at which the kinetic energy of the mean motion is transformed into eddy energy can be expressed by the formula

$$(1) \qquad \iiint_V c_M\left[\left(\frac{\partial u}{\partial h}\right)^2+\left(\frac{\partial v}{\partial h}\right)^2\right]dx\,dy\,dh$$

During turbulent stirring of the air a certain part of the eddy energy is transformed into potential and thermal energy. The rate of this energy conversion is, according to Richardson:

$$(2) \qquad \iiint_V c_H\,\frac{g}{T}\,(\alpha_0-\alpha)\,dx\,dy\,dh$$

Here c_H represents the eddy convectivity, g the gravity acceleration, T the absolute temperature, α_0 the adiabatic, and α the actual, vertical lapse rate of temperature. It is seen from (2) that in the case of superadiabatic lapse rate the process is reversed, i. e., potential and thermal energy are then transformed into turbulent energy.

Through the action of molecular viscosity a certain fraction of E' is transformed into heat. For this fraction Richardson gives the expression

$$(3) \qquad \nu E',$$

where the coefficient ν depends upon the linear dimensions of the eddies. If we assume, however, that their size remains constant throughout the portion considered, we may regard ν as a constant.

If throughout the boundary there is no transport of eddies to or from V, then the sum of the quantities (1), (2), and (3), each taken with its proper sign, must be equal to the total change in E'. Thus we get Richardson's equation

$$(4) \qquad \frac{\partial E'}{\partial t}=\iiint_V\left\{c_M\left[\left(\frac{\partial u}{\partial h}\right)^2+\left(\frac{\partial v}{\partial h}\right)^2\right]-c_H\,\frac{g}{T}\,(\alpha_0-\alpha)\right\}dx\,dy\,dh-\nu E'$$

Let us now apply (4) to an atmospheric system of unit cross section and height dh. The equation (4) then changes into

$$(5) \qquad \rho\,\frac{\partial E}{\partial t}\,dh=c_M\left[\left(\frac{\partial u}{\partial h}\right)^2+\left(\frac{\partial v}{\partial h}\right)^2\right]dh-c_H\,\frac{g}{T}\,(\alpha_0-\alpha)\,dh-\nu\rho E dh$$

Here E denotes the eddy energy per unit mass. To the second member of this equation there must be added an expression for the rate of inflow of eddy energy through the boundaries.

[1] A very complete table of observed values of c_M is given by L. F. Richardson in "Weather Prediction by Numerical Process," Cambridge, the University Press, 1922.

We know that turbulence gives rise to a vertical transfer of horizontal momentum with the components

$$-c_M\frac{\partial u}{\partial h},\quad -c_M\frac{\partial v}{\partial h}$$

In the same way the eddy transfer of potential temperature (θ) can be expressed in the form:

$$-c_H\frac{\partial \theta}{\partial h}$$

Now, it is known from experience that eddies are able to diffuse from one layer to another; in fact, this is what we observe on a large scale when we watch the growth of the summertime cumulus clouds. We assume as an approximate expression for the rate of this diffusion of eddy energy:

$$-c_E\frac{\partial E}{\partial h},$$

which is analogous to the formulae for the eddy transfer of heat and momentum previously given. A similar expression has already been proposed by Richardson.[2]

Taking into account this vertical diffusion of eddy energy, we finally obtain:

$$\rho\frac{\partial E}{\partial t}=c_M\left[\left(\frac{\partial u}{\partial h}\right)^2+\left(\frac{\partial v}{\partial h}\right)^2\right]-c_H\cdot\frac{g}{T}(\alpha_o-\alpha)-\nu\rho E+\frac{\partial}{\partial h}\left[c_E\frac{\partial E}{\partial h}\right] \tag{6}$$

As long as the relations between c_M, c_H, c_E, and E are unknown, the equation (6) is of little value. If c_M, c_H, and c_E could be expressed in terms of E, then the solution of (6), together with certain boundary conditions, ought to give the vertical distribution of eddy energy corresponding to given values of α and $\left(\frac{\partial u}{\partial h}\right)^2+\left(\frac{\partial v}{\partial n}\right)^2$.

We know that in systems where the average size of the eddies remains constant the quantities c_M, c_H, and in all probability also c_E, increase with E. Furthermore, we know that they disappear for $E=O$. Consequently, as a first approximation, we may introduce the expressions:

$$\begin{aligned}c_E&=aE\\ c_M&=bE\\ c_H&=cE,\end{aligned} \tag{7}$$

where a, b, and c are constants. From observation it has been found[3] that

$$c_M=c_H \tag{8a}$$

Therefore,

$$b=c. \tag{8b}$$

In the numerical examples given later the identities (8a) and (8b) are extended to include also c_E and a, viz,

$$a=b=c. \tag{8c}$$

[1] Richardson's expression does not apply to the eddy energy per mass (E) but to the "potential eddy energy per mass," $E\left(\frac{\rho_1}{\rho}\right)^{\frac{2}{3}}$, referred to some standard density ρ_1. Richardson arrives at this expression through the application of thermodynamical methods to the study of eddies. He proves that if a large air volume containing numerous eddies is expanded $E\left(\frac{\rho_1}{\rho}\right)^{\frac{2}{3}}$ remains constant. Thus the eddies behave like the molecules of a monatomic gas. For the schematic theory outlined in the following pages we shall, however, use the simpler diffusion expression given above.

[2] This was first suggested by Taylor (Phil. Transactions, London, 1915) and later confirmed by Richardson.

It must be kept clearly in mind that through this assumption real conditions are depicted only in their rough outlines. This becomes still plainer if we remember that c_M probably has two very different values for the transport of momentum parallel to the wind and across the wind (Richardson, "Weather Prediction by Numerical Process," page 73.)

Combining (6), (7), and (8), we obtain

$$\rho\frac{\partial E}{\partial t}=a\frac{\partial}{\partial h}\left[\frac{\partial E}{\partial h}\right]+E\left\{b\left[\left(\frac{\partial u}{\partial h}\right)^2+\left(\frac{\partial v}{\partial h}\right)^2\right]-b\cdot\frac{g}{T}(\alpha_o-\alpha)-\nu\rho\right\} \tag{9}$$

From this equation it should be possible to derive the vertical distribution of E as well as the change of E with time, when the boundary conditions are given. If the equation (9) can be verified and the constants a, b, and ν properly determined, then it offers one great advantage for the determination of E. Computing c_M and thus also E in the ordinary way from the hydrodynamical equations, we obtain the formula

$$c_M(h_1)=\frac{c_M(h_2)\left(\frac{\partial u}{\partial h}\right)_{h_2}+2\rho\Omega\sin\varphi\int_{h_1}^{h_2}v\,dh}{\left(\frac{\partial u}{\partial h}\right)_{h_1}}.$$

The x-axis runs in the direction of the gradient wind. Ω is the angular velocity of the earth and φ the latitude. c_M is therefore expressed as a ratio between two quantities which in a rather short distance from the ground rapidly approach zero. Thus a hydrodynamical determination of c_M for greater heights becomes almost impossible. This difficulty is avoided by use of the equation (9).

It is easily seen that on account of the diffusion term $a\frac{\partial}{\partial h}\left[E\frac{\partial E}{\partial h}\right]$ the equation (9) is no longer linear. This means, mathematically, that the sum of two partial solutions of (9) will not give a new solution. Attempts have been made to differentiate between "thermal" and "dynamical" turbulence, the latter being the turbulence which is supplied exclusively from the kinetic energy of the mean motion. It is easily seen from (9) that the two kinds of turbulence react upon each other. Attempts to differentiate between them must therefore be futile. However, if we assume an atmosphere in which the components u and v of the mean motion vanish, we may speak of a pure convective or thermal turbulence. In the same way it is possible to discuss a pure dynamical turbulence, if the study is limited to an incompressible liquid, for instance a turbulent river. In the following section some integrals of (9) for the limiting case of pure convective turbulence are given.

Before deriving these integrals we shall, however, draw one conclusion of a more general character from (9). Under stationary conditions this equation takes the form

$$a\frac{\delta}{\delta h}\left[E\frac{\delta E}{\delta h}\right]+\psi' E=O \tag{10}$$

where

$$\psi'=\left\{b\left[\left(\frac{\delta u}{\delta h}\right)^2+\left(\frac{\delta v}{\delta h}\right)^2\right]-b\cdot\frac{g}{T}(\alpha_o-\alpha)-\nu\rho\right\} \tag{11}$$

Now integrate (10) between H_1 and H_2 and suppose that $E\frac{\delta E}{\delta h}$ is equal to zero at these limits. The result is:

$$\int_{H_1}^{H_2}\psi'\cdot E\,dh=O. \tag{12}$$

Since E is essentially positive, the integral (12) can not vanish unless ψ' changes its sign at least once between H_1 and H_2 or remains equal to zero in the entire interval. In layers where ψ' is positive, eddies are produced; where ψ' is negative, eddies are consumed. Since consumption and production of eddies are proportional to ψ', we may introduce for this quantity the name "eddy productivity." Thus: If within a volume V the state of turbulence is stationary and through the boundaries no transport of eddies takes place, then V must contain eddy producing as well as eddy consuming layers. In the atmosphere the eddy producing layers are generally found next to the ground, where the vertical increase of wind velocity and the temperature gradient have their greatest values. The upper layers, in which the wind remains more or less constant and the temperature lapse rate has a smaller value, are generally eddy consuming.

II. CONVECTIVE TURBULENCE IN THE FREE ATMOSPHERE

All through this section it will be assumed that the velocity components of mean motion (u, v) vanish. The eddy productivity ψ' therefore reduces to

$$\psi' = -\left\{b \cdot \frac{g}{T}(\alpha_0 - \alpha) + \nu\rho\right\}.$$

As has been pointed out, the numerical value of ν largely depends on the size of the eddies. Assuming their average linear dimensions to be about 10 meters, Richardson finds for ν a value of $2.6.10^{-4}$ sec.$^{-1}$. This means that frictional forces alone would in 24 hours reduce a given supply of eddy energy to 0.8 of its original value. Now it is seen from the expression (I, 11) that the vertical stability of stratification acts upon the eddies in the same way as does the friction. Through the numerical examples treated below it will be shown that the smothering influence of the vertical stability is far more effective than that of the viscosity. Therefore, it seems justifiable to neglect in the expression for the eddy productivity the term $\nu\rho$, at least when the lapse rate is not too close to the adiabatic. Thus we get

$$\psi' = -b \cdot \frac{g}{T}(\alpha_0 - \alpha) \tag{13}$$

Let us now suppose that in an unlimited atmosphere the following temperature distribution is maintained through radiation. In a certain layer, between $h = -H$ and $h = +H$, the lapse rate is constant and superadiabatic,

$$\alpha > \alpha_0.$$

In the adjacent layers the lapse rate is constant and less than adiabatic,

$$\alpha_1 < \alpha_0.$$

In the intermediate layer we have a positive eddy productivity,

$$\psi_0' = b \cdot \frac{g}{T}(\alpha - \alpha_0).$$

In the surrounding layers the eddy productivity is negative,

$$\psi_1' = -b \cdot \frac{g}{T}(\alpha_0 - \alpha_1).$$

If the variations in T be neglected, then the quantities ψ_0' and ψ_1' may be considered as constants. We shall now try to compute a stationary distribution of eddy energy E, that corresponds to the given distribution of eddy productivity. Under stationary conditions the fundamental equation (I, 9) has the form:

$$a\frac{\delta}{\delta h}\left[E\frac{\delta E}{\delta h}\right] + E\psi' = 0.$$

Let us first discuss the intermediate layer. There we have

$$\frac{\delta}{\delta h}\left[E\frac{\delta E}{\delta h}\right] + \psi_0 E = 0, \tag{14}$$

where

$$\psi_0 = \frac{b}{a}\frac{g}{T_0}(\alpha - \alpha_0) \tag{15}$$

T_0 is the absolute temperature at the center of this layer. The equation (14) can be written

$$\frac{\delta E}{\delta h} \cdot \frac{\delta}{\delta E}\left(E\frac{\delta E}{\delta h}\right) + \psi_0 \cdot E = 0,$$

or

$$2E\frac{\delta E}{\delta h} \cdot \frac{\delta}{\delta E}\left(E\frac{\delta E}{\delta h}\right) = -2\psi_0 \cdot E^2$$

Integrating with respect to E, we obtain

$$E^2\left(\frac{\delta E}{\delta h}\right)^2 = C - \frac{2\psi_0}{3}E^3. \tag{16}$$

Since the variation of T with height has been neglected, it is obvious that E must be symmetrical with regard to h. Thus $\frac{\delta E}{\delta h}$ must vanish for $h = 0$. If we denote by E_0 the value of E at this height, we can write (16) in the form

$$E^2\left(\frac{\delta E}{\delta h}\right)^2 = \frac{2\psi_0}{3}(E_0^3 - E^3). \tag{16b}$$

Now let us introduce the quantity

$$\frac{E}{E_0} = z. \tag{17}$$

Then we get

$$z\frac{\delta z}{\delta h} = -\sqrt{\frac{2\psi_0}{3E_0}}\sqrt{1 - z^2}, \tag{18}$$

or, after integration,

$$\int_1^z \frac{z\,dz}{\sqrt{1 - z^2}} = -\sqrt{\frac{2\psi_0}{3E_0}}\,h. \tag{19}$$

In the surrounding layers we have

$$\frac{\delta}{\delta h}\left[E\frac{\delta E}{\delta h}\right] - \psi_1 E = 0, \tag{20}$$

where

$$\psi_1 = \frac{b}{a}\frac{g}{t_0}(\alpha_0 - \alpha_1). \tag{21}$$

Treating this equation in the same way as (14), we obtain

$$2E\frac{\delta E}{\delta h}\frac{\delta}{\delta E}\left(E\frac{\delta E}{\delta h}\right) = 2\psi_1 E^2$$

or, after integration,

$$E^2\left(\frac{\delta E}{\delta h}\right)^2 = K + \frac{2\psi_1}{3}E^3. \tag{22}$$

The eddies which are generated in the intermediate layer and diffuse upward and downward will gradually be consumed in the surrounding layers and their energy will be transformed into potential and thermal energy. At a certain distance the dissipation of the eddy energy will be complete, i. e., we there have $E=O$. Since $\frac{\delta E}{\delta h}$ in any case can not be infinite at this height, it follows that

$$K=O.$$

The equation (22) therefore is simplified to

$$\left(\frac{\delta E}{\delta h}\right)^2=\frac{2\psi_1}{3}\cdot E. \tag{23}$$

This gives, after integration,

$$E=\frac{\psi_1}{6}\cdot(H_1-h)^2. \tag{24}$$

H_1 is the constant of integration and gives the height at which the eddy energy is totally dissipated.

Let us next discuss the conditions at the boundaries between the layers. There the following requirements must be fulfilled:

(1) The diffusion stream of eddy energy must be continuous.

(2) The eddy energy E must be continuous.

If we denote by E_1 the value of E for $h=H$, then we obtain from these conditions and from the equations (16b) and (23),

$$\frac{2\psi_1}{3}E_1^3=\frac{2\psi_o}{3}(E^3{}_o-E_1^3), \tag{25}$$

or

$$\frac{E_1}{E_o}=\sqrt[3]{\frac{\psi_o}{\psi_o+\psi_1}}=\sigma(<1). \tag{26}$$

Combining (26) and (19), we obtain

$$-q=\int_1^\sigma\frac{z\,dz}{\sqrt{1-z^3}}=-\sqrt{\frac{2\psi_o}{3E_o}}\cdot H. \tag{27}$$

Since σ is a known quantity, q can be computed and we are therefore able to determine E_o from the equation (27). The result is

$$E_o=\frac{2\psi_o}{3q^2}\cdot H^2 \tag{28}$$

We still have to compute the constant H_1. From (24) it follows that

$$\sqrt{\frac{6E_o\sigma}{\psi_1}}+H=H_1 \tag{29}$$

or

$$H_1=H\left(1+\frac{2}{q}\sqrt[6]{\frac{\psi_o^4}{\psi_1^3(\psi_o+\psi_1)}}\right). \tag{30}$$

From the formulæ (28) and (30) it is seen that the maximum intensity of the eddy energy is proportional to the square of the height of the eddy-producing layer. The total height of the turbulent layer is proportional to the height of the eddy-producing layer. In the table below the solution of the problem is given in a condensed form.

(A) between $h=O$ and $h=H$

$$\sigma=\sqrt[3]{\frac{\psi_o}{\psi_o+\psi_1}} \qquad E=zE_o$$

$$q=\int_\sigma^1\frac{z\,dz}{\sqrt{1-z^3}} \qquad \varphi(z)=\int_z^1\frac{z\,dz}{\sqrt{1-z^3}}=\sqrt{\frac{2\psi_o}{3E_o}}h$$

$$E_o=\frac{2\psi_o}{3q^2}H^2$$

(B) between $h=H$ and $h=H_1$

$$H_1=H\left(1+\frac{2}{q}\sqrt[6]{\frac{\psi_o^4}{\psi_1^3(\psi_o+\psi_1)}}\right)$$

$$E=\frac{\psi_1}{6}(H_1-h)^2.$$

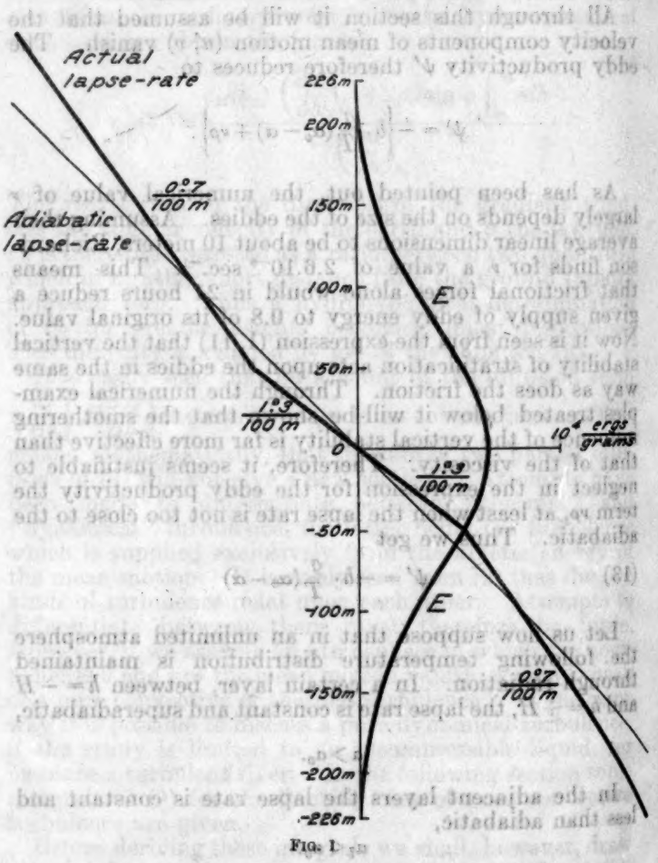


FIG. 1.

As an illustration of this integral a numerical example has been computed and plotted in Figure 1. The thickness 2H of the superadiabatic layer has been assumed to be 100 m., the superadiabatic lapse rate α 1.3° C. per 100 m., and the lapse rate in the surrounding layers 0.7° C. It is seen from the diagram that the height at which the eddy current from the superadiabatic layer totally disappears, is equal to 226 m. This value is independent of the numerical value of the ratio $\frac{b}{a}$, and should therefore be rather reliable. The maximum value of the eddy energy is equal to 0.64. $10^4\ \frac{\text{ergs}}{\text{gram}}$.

In Figure 2 a diagram is given of the elliptic integral

$$\varphi(z)=\int_z^1 \frac{z\,dz}{\sqrt{1-z^3}},$$

which occurs in the solution given above.

It may seem absurd and in contradiction with observed conditions that a superadiabatic layer like the one here assumed should not exert its effects through more than 226 m. in each direction, especially if we compare this result with conditions on a clear, warm summer afternoon, when the convection currents from a rather thin superadiabatic layer at the surface extend thousands of meters in height. We must, however, keep in mind, that we have assumed the eddy producing layer to be surrounded by stable air masses with a lapse rate of 0.7° C. per 100 m., while in the case of summer convection the superadiabatic gradient in the bottom layer is followed above by an adiabatic lapse rate extending practically as far as the convection currents themselves. Therefore, the numerical example just treated illustrates how effective even the comparatively high gradient of 0.7° C. is in suppressing turbulence. Thus we may conclude, that the eddies created in the lower layers of a stable air mass as soon as there is wind, are able to diffuse upward only with great difficulty. In this respect the stable atmosphere differs widely from an homogeneous incompressible fluid, for instance a river, where only frictional forces counteract the upward diffusion of the turbulence from the bottom layers.

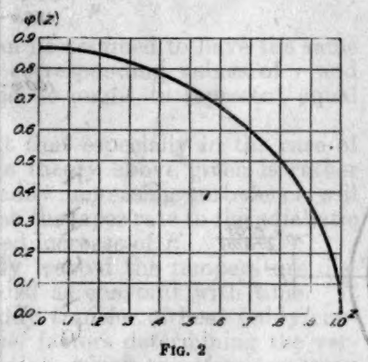


FIG. 2

Returning to the fundamental equation (I, 9) we shall now compute how an initial, limited eddy supply is diffused upward and downward under different temperature conditions. Assume the atmosphere to be unlimited and the vertical lapse rate to be $\alpha<\alpha_o$. The equation then takes the form

$$\frac{\rho}{a}\frac{\delta E}{\delta t}=\frac{\delta}{\delta h}\left[E\frac{\delta E}{\delta h}\right]-\psi E, \tag{31}$$

where

$$\psi=\frac{b}{a}\frac{g}{T}(\alpha_o-\alpha). \tag{32}$$

Here T is regarded as a constant. If we introduce new variables,

$$\tau=\frac{a\psi t}{\rho} \tag{33}$$

and

$$x=h\sqrt{\psi}, \tag{34}$$

then the equation (31) can be simplified to

$$\frac{\partial E}{\partial \tau}=\frac{\partial}{\partial x}\left[E\frac{\partial E}{\partial x}\right]-E. \tag{35}$$

Suppose the eddy disturbance E to be limited to a region

$$-\sqrt{\frac{l}{m}}<x<+\sqrt{\frac{l}{m}}$$

and assume for E the analytical form

$$E=l-mx^2. \tag{36}$$

In this expression l and m are functions of τ. Substituting this expression for E in (35), we find

$$(l'+l)-(m'+m)x^2+\frac{\partial}{\partial x}(2lmx-2m^2x^3)=O,$$

or

$$(l'+l)-(m'+m)x^2+2lm-6m^2x^2=O. \tag{37}$$

The primes indicate differentiation with respect to τ. From (37) it is evident that the following requirements must be fulfilled, namely:

$$\begin{aligned} l'+l+2lm&=O\\ m'+m+6m^2&=O. \end{aligned} \tag{38}$$

The second equation (38) gives after integration

$$m=\frac{m_o e^{-\tau}}{6m_o+1-6m_o e^{-\tau}} \tag{39}$$

and the first

$$l=\frac{l_o e^{-\tau}}{\sqrt[3]{6m_o+1-6m_o e^{-\tau}}}. \tag{40}$$

Here l_o and m_o are the values of l and m for the time $\tau=O$. The upper limit (H) for the turbulent layer is given by the equation:

$$H^2=\frac{l}{m\psi}$$

or

$$H^2=\frac{l}{m_o\psi}[(6m_o+1)-6m_o e^{-\tau}]^{\frac{1}{3}}.$$

Taking the square root of each member, we obtain

$$2H=2H_o\sqrt[3]{6m_o+1-6m_o e^{-\tau}}. \tag{41}$$

$2H$ is the thickness of the turbulent layer at the time τ and $2H_o$ the thickness of the same layer at the time O. We see that the velocity of the diffusion decreases more and more. The layers outside of

$$\pm H_\infty=\pm H_o\sqrt[3]{6m_o+1} \tag{42}$$

will remain unaffected by the eddies.

The total amount of eddy energy, given by the expression

$$K=\int_{-H}^{+H} E\,dh$$

is equal to

$$K=\frac{4}{3}lH.$$

It is easily found that this expression has the value

$$K=K_o e^{-\frac{a\psi t}{\rho}} \tag{43}$$

K_o means the total eddy energy at the time $t=0$. The total turbulent energy decreases more and more; at the time $t=\infty$, when the disturbance has reached the limits $\pm H_\infty$, all the eddy energy has been consumed and transformed into potential and thermal energy.

Now suppose that the lapse rate has such a value that the eddy productivity disappears, i. e., let us assume

$$b\frac{g}{T}(\alpha_o-\alpha)+\nu\rho=0.$$

The diffusion equation then reduces to

$$\frac{\partial E}{\partial \tau}=\frac{\partial}{\partial h}\left[E\frac{\partial E}{\partial h}\right] \tag{44}$$

where

$$\tau=\frac{at}{\rho}. \tag{45}$$

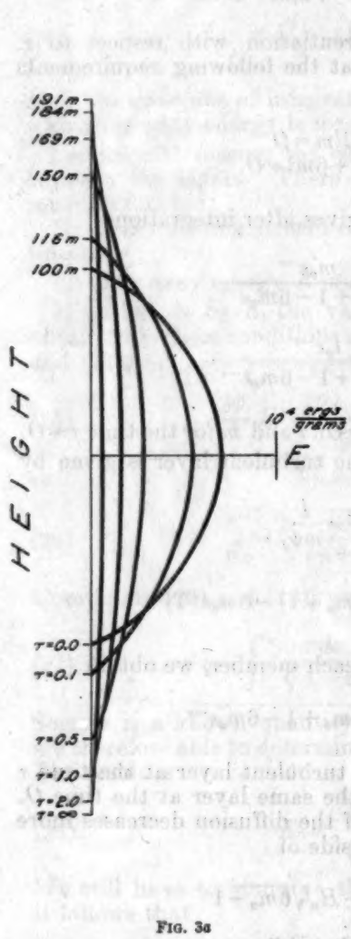


FIG. 3a

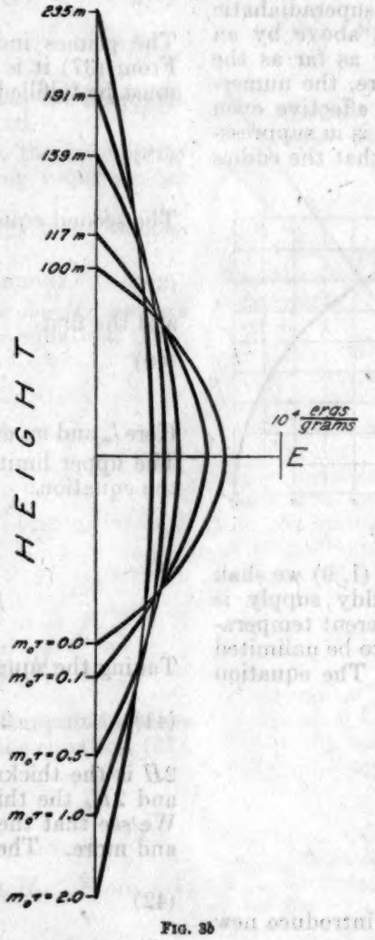


FIG. 3b

In this case the corresponding solution takes the form:

$$E=l-mh^2 \tag{46}$$

$$l=\frac{l_o}{\sqrt[3]{1+6m_o\tau}}$$

$$m_o=\frac{m_o}{1+6m_o\tau}$$

$$H=H_o\sqrt[3]{1+6m_o\tau}.$$

It is seen that the disturbance now will travel toward the infinite, but with decreasing velocity. The total eddy energy in this case remains constant.

Finally consider the case of unstable stratification, where $\alpha>\alpha_o$.

The diffusion equation then has the form

$$\frac{\partial E}{\partial \tau}=\frac{\partial}{\partial x}\left[E\frac{\partial E}{\partial x}\right]+E, \tag{47}$$

where

$$\tau=\frac{a\psi t}{\rho}$$

$$x=h\sqrt{\psi} \tag{48}$$

$$\psi=\frac{b}{a}\frac{g}{T}(\alpha-\alpha_o)$$

The integral is

$$E=l-m\psi h^2$$

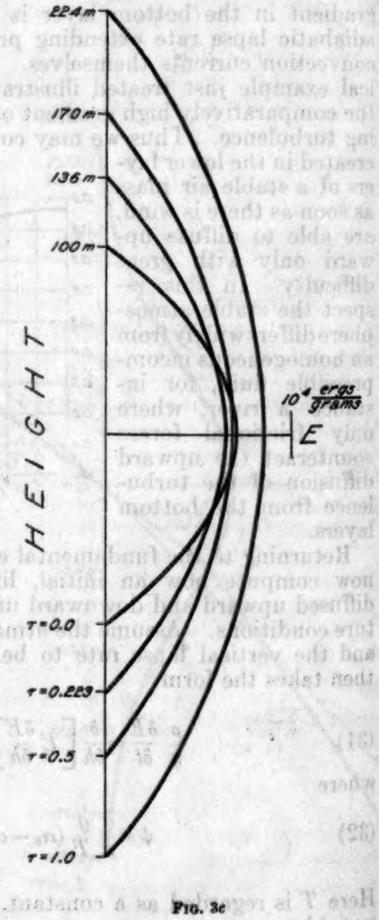


FIG. 3c

$$l=\frac{l_o e^{\tau}}{\sqrt[3]{6m_o e^{\tau}+(1-6m_o)}} \tag{49}$$

$$m=\frac{m_o e^{\tau}}{6m_o e^{\tau}+1-6m_o}$$

$$H=H_o\sqrt[3]{6m_o e^{\tau}+(1-6m_o)}.$$

We see that the disturbance travels toward infinity with an increasing velocity. The total eddy energy (K) increases at the rate

$$K=K_o e^{\frac{a\psi t}{\rho}},$$

the potential energy of the unstable stratification rapidly becoming transformed into eddy energy.

In Figures 3a, 3b, and 3c are given graphical representations in (E, h)-diagrams of this process of eddy diffusion during stable, neutral, and unstable stratifications.

In all three cases the initial disturbance is supposed to have the same form and magnitude; its maximum value for $h=O$ is $7\cdot10^3 \frac{\text{ergs}}{\text{gram}}$. For the stable lapse rate we have assumed the value 0.8° C./100 m. and for the unstable 1.2° C./100 m. Thus, if we put

$$\frac{b}{a}=1, \quad \frac{g}{T_o}=3.5$$

we get, in both cases,

$$\tau=7\cdot10^{-5}\frac{a}{\rho}t.$$

During neutral stratification the corresponding equation is

$$\tau=\frac{a}{\rho}t.$$

However, in that case m_o has the value $7\cdot10^{-5}$ and we obtain

$$m_o\tau=7\cdot10^{-5}\frac{a}{\rho}t.$$

Therefore, as long as a can be assumed to have the same value in all three cases, corresponding values of τ and $m_o\tau$ in figures 3a, 3b, and 3c ought to represent equal time intervals.

It must be pointed out that especially in the case of unstable stratification the theory above given is rather unsatisfactory. The steadily increasing turbulence will constantly tend to diminish the lapse rate to the adiabatic and thus prevent unlimited increase of E.

In the examples already treated the temperature distribution has been regarded as constant with time. It is well known that the eddy transfer of heat (eddy convection) is one of the chief factors determining the vertical temperature distribution, which therefore, contrary to the assumption hitherto made, generally varies with changes in the eddy distribution. If the potential temperature be denoted by θ, then the equation for heat convection by means of eddies has the form

$$\rho\frac{\partial\theta}{\partial t}=\frac{\partial}{\partial h}\left[c_H\frac{\partial\theta}{\partial h}\right] \tag{50}$$

Substituting from (I, 7), the expression for C_H, we obtain

$$\rho\frac{\partial\theta}{\partial t}=c\frac{\partial}{\partial h}\left[E\frac{\partial\theta}{\partial h}\right]. \tag{51}$$

In the general convection problem this equation must be solved simultaneously with (I, 9). If the quantities T and α, which occur in (I, 9) are expressed in terms of θ, it is easily seen that

$$\frac{1}{T}(\alpha_o-\alpha)=\frac{1}{T}\left(\alpha_o+\frac{\partial T}{\partial h}\right)=\frac{1}{\theta}\frac{\partial\theta}{\partial h}. \tag{52}$$

Thus the equations, which determine atmospheric convection, are

$$\rho\frac{\partial E}{\partial t}=a\frac{\partial}{\partial h}\left[E\frac{\partial E}{\partial h}\right]-c\cdot g\cdot\frac{E}{\theta}\frac{\partial\theta}{\partial h} \tag{53a}$$

$$\rho\frac{\partial\theta}{\partial t}=c\cdot\frac{\partial}{\partial h}\left[E\frac{\partial\theta}{\partial h}\right] \tag{53b}$$

General solutions of this system are not easily obtained. If, however, we assume $a=c$, and substitute a constant instead of θ in the last term of (53a), then one simple integral can be obtained, which may have some bearing upon the rise of cumuli on summer days. Introducing the new variable

$$\tau=\frac{at}{\rho}=\frac{ct}{\rho}$$

and putting

$$\frac{g}{\theta}=q \text{ (constant)},$$

we may write our equations in the form

$$\frac{\partial E}{\partial\tau}=\frac{\partial}{\partial h}\left[E\frac{\partial E}{\partial h}\right]-qE\cdot\frac{\partial\theta}{\partial h} \tag{54a}$$

$$\frac{\partial\theta}{\partial\tau}=\frac{\partial}{\partial h}\left[E\frac{\partial\theta}{\partial h}\right] \tag{54b}$$

Now suppose that in the layer $-H<h<+H$ the temperature gradient is superadiabatic, i. e., the potential temperature falling,

$$\theta=\theta_O-\alpha h\ (\alpha>O). \tag{55}$$

In the same layer the eddy energy is assumed to be distributed according to the law

$$E=k-lh^2=l(H^2-h^2) \tag{56}$$

$$\frac{k}{l}=H^2 \tag{57}$$

For $h>+H$ the temperature gradient is adiabatic, i. e., the potential temperature θ_1 constant,

$$\theta_1=\theta_O-\Delta.$$

For $h<-H$ we have another constant potential temperature

$$\theta_2=\theta_O+\Delta$$

The eddy energy is zero for $h>+H$ and $h<-H$.

The quantities a, k, and l are functions of τ, which must be so determined that the expressions (55) and (56) for E and θ satisfy the equations (54).

From (54b) and (55) we obtain

$$-\alpha' h=+2hl\alpha \qquad \left(f'=\frac{\partial f}{\partial\tau}\right)$$

or

$$\alpha'=-2\alpha l. \tag{58}$$

In the same way we obtain from (54a), (55) and (56)

$$k'-l'h^2-\alpha q(k-lh^2)+2lk-6l^2h^2=O$$

or

$$k'-\alpha qk+2lk-h^2(l'-\alpha ql+6l^2)=O.$$

Since this equation must be fulfilled for any value of h, we obviously must have

$$k'-\alpha qk+2lk=O. \tag{59}$$

$$l'-\alpha lq+6l^2=O. \tag{60}$$

Eliminating l between (58) and (60), we obtain, after integration,

$$\alpha = \frac{\alpha_0}{1+\frac{\alpha_0 q\tau}{2}}, \tag{61}$$

where α_0 is the value of α for the time $\tau = O$. In the same way we get

$$l = \frac{\alpha_0 q}{4\left(1+\frac{\alpha_0 q\tau}{2}\right)} \tag{62}$$

and, from (59), (61), and (62),

$$k = C\left(1+\frac{\alpha_0 q}{2}\tau\right), \tag{63}$$

where C is a constant of integration. This constant can be determined in the following way. We have

$$\theta_1 = \theta_0 - \Delta = \theta_0 - \alpha H$$

or

$$\Delta^2 = \alpha^2 H^2,$$

and, according to (57)

$$H^2 = \frac{k}{l}.$$

Thus

$$\Delta^2 = \alpha^2 \frac{k}{l},$$

or

$$\Delta^2 = \frac{\alpha_0^2}{\left(1+\frac{\alpha_0 q\tau}{2}\right)^2} \cdot \frac{C\left(1+\frac{\alpha_0 q\tau}{2}\right)\cdot 4 \cdot \left(1+\frac{\alpha_0 q\tau}{2}\right)}{\alpha_0 q} = \frac{4C\alpha_0}{q}.$$

Therefore

$$C = \frac{q\Delta^2}{4\alpha_0}. \tag{64}$$

For H we obtain

$$H = \sqrt{\frac{k}{l}} = \frac{\Delta}{\alpha_0}\left(1+\frac{\alpha_0 q\tau}{2}\right). \tag{65}$$

The solution may be written in the following condensed form:

$$\sigma = \frac{q\alpha_0}{2};\quad \alpha_0 H_0 = \Delta$$

$$H = H_0(1+\sigma\tau)$$

$$\alpha = \frac{\alpha_0}{1+\sigma\tau} = \frac{\Delta}{H} \tag{66}$$

$$\theta = \theta_0 - \frac{\Delta}{H}h$$

$$E = \frac{q\Delta}{4H}(H^2 - h^2).$$

The constant velocity of diffusion is equal to

$$H_0\sigma \cdot \frac{a}{\rho} = \frac{q\Delta}{2}\frac{a}{\rho}\ cm/sec. \tag{67}$$

If in both the surrounding layers the lapse rate is less than adiabatic, then the velocity of diffusion obviously has a smaller value than that computed above.

In Figure 4 a graphical illustration of the solution (66) is given. At the time $\tau = O$ the superadiabatic layer has a thickness of 200 m.; the difference in potential temperature between the upper and the lower air masses is equal to 6° C. The distribution of eddy energy at different times is given by parabolae. The potential temperature of the turbulent layer is represented by a bundle of straight lines through the point O. It is seen from the figure, how the eddy layer spreads, while at the same time the superadiabatic lapse rate more and more decreases.

The difference in potential temperature between the upper and lower air layers in the numerical example just given may seem rather great. It is therefore appropriate to show that such differences really occur in the free atmosphere. The kite ascent at Mount Weather for October 2, 1913 (*4*) gives between 2,711 m. and 4,102 m., a temperature lapse rate of about 1.5° C. per 100 m. and in the interval 3,020 m.—3,730 m. even 1.7° C. This corresponds to an upward decrease in potential temperature of about the same magnitude as that assumed above. The reason why in this case the superadiabatic lapse rate can be maintained long enough to make it possible for us to measure it with our instruments may probably be sought in the very stable stratification of the lower air layers (between 1,999 m. and 2,673 m. the ascent gives a lapse rate of 0.6° C. per 100 m.), through which disturbances from the ground are prevented from diffusing upward.

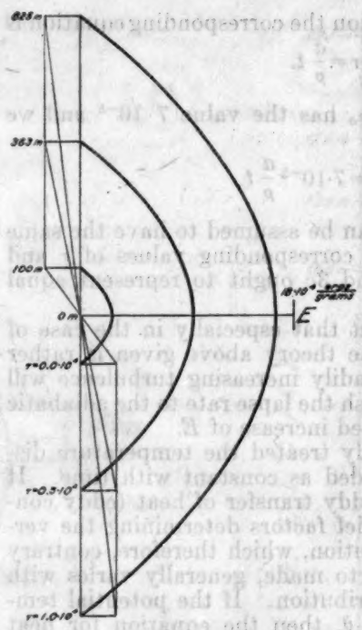


FIG. 4

The solution just derived may be applied to the discussion of the cause of certain thunderstorms. It has been observed, especially in higher latitudes, that thunderstorms frequently occur in the south quadrant of barometric depressions. This is explained by Humphreys (*5*) in the following way: The movement of the upper atmospheric strata follows the isobars, i. e., in the south quadrant of a depression the wind aloft is westerly. The surface wind is—on account of friction against the ground—deviated toward the center of the depression. Thus, in the south quadrant we have a southwesterly surface wind which, coming from lower latitudes, generally brings air masses which potentially are warmer than the masses transported with the upper west wind. In this way an unstable temperature distribution is created, which to a certain extent corresponds to the one here assumed, and a more or less violent overturning of the air sets in. In an unpublished paper by Mr. H. L. Choate, of the United States Weather Bureau, similar

considerations have been applied as a more general explanation of cyclonic rains over the United States.[1]

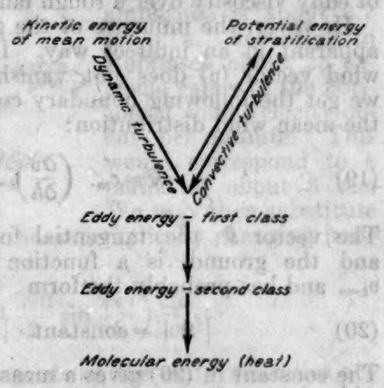
III. BOUNDARY CONDITION

Observations show that within the lowest air layers the atmospheric eddy viscosity c_M very rapidly decreases the more we approach the ground. Since we have assumed

$$c_M = aE, \tag{1}$$

where a is a constant, this should indicate that E, also, decreases with decreasing height above the surface. However, the coefficient a is a constant only as long as the average size of the eddies remains the same. Now the eddies in the surface layer are very small. They increase in size with distance from the ground. The above conclusion is therefore not justified.

Taking into account the variation of the size of the eddies, a should no longer be regarded as a constant but as a function of the height (h). In the same way the coefficients b, c, and ν should be replaced by functions of h. In order to avoid the difficulties arising from these more general expressions for a, b, c, and ν we may use the following method: Instead of regarding the dimensions of the eddies as continuously varying quantities, we will assume that all eddies can be grouped into two distinctly separate classes of entirely different magnitudes. In the first class we count all the large eddies of the free atmosphere. Only eddies belonging to this class are of significance for atmospheric eddy convectivity and viscosity. The eddies of the second class are smaller; in the same way as we neglect molecular heat conduction and friction compared with the eddy transfer of heat and momentum, we will also neglect the transfer of heat and mean momentum through eddies of the second class compared with the corresponding transport through eddies of the first class. It is well known that large eddies generally disintegrate into smaller and smaller eddies, which rapidly disappear under the action of molecular viscosity. Thus we obtain the scheme for energy transformations in the atmosphere, illustrated above.



We shall here make an additional assumption, namely, that the amount of eddy energy of the second class, which is formed directly from the kinetic energy of the mean motion or from the potential energy of stratification, must be small compared with the amount of eddy energy of the first class produced during the same time.

It is probable that sometimes several small eddies join to form a large eddy, but since we know nothing about this process it will not be considered here.

Under the assumptions made above, the equation (I, 6) can be used unaltered as an energy equation for eddies of the first class. E now means not the total eddy energy per unit mass but the eddy energy of the first class. νE gives the percentage of E, which per unit time is transformed into eddy energy of the second class. The interpretation of the other terms is obvious.

[1] This paper was presented at the April, 1924, meeting of the American Meteorological Society.

Now let us return to the boundary conditions. If only eddies of the first class are considered, then the relation (1), where a is a constant, may still be supposed to be fulfilled. Since c_M very rapidly goes toward zero when we approach the ground, it must be concluded that the value of E for $h=0$ is equal to zero. Now we will assume that in the same way as the kinetic energy of the mean motion is very rapidly converted into eddies at the surface and in the lowest layer, where the rate of sheering is strongest, in the same way eddies of the first class are dissolved into smaller eddies along the ground on account of friction at the surface. This loss (M) of eddy energy of the first class at the ground must obviously be equal to the downward eddy diffusion current at the surface, thus

$$M = \left(aE\frac{\partial E}{\partial h}\right)_{h=0} \tag{2}$$

Since E is equal to zero for $h=0$, this means that $\left(\frac{\partial E}{\partial h}\right)_{h=0}$ must be infinite. Hence we get in the lowest layer a development for E of the form

$$\frac{a}{2}\frac{\partial E^2}{\partial h} = M + M_2 h + M_3 h^2 + \cdots$$

or

$$E = \sqrt{\frac{2M}{a}}\sqrt{h}\ (1 + \text{terms of higher order}) \tag{3}$$

IV. STATIONARY DISTRIBUTION OF E

The above obtained boundary condition may now be used for determining the vertical distribution of E under stationary conditions. For that purpose we must return to the equation

$$\frac{\delta}{\delta h}\left[E\frac{\delta E}{\delta h}\right] + \psi E = 0, \tag{1}$$

where

$$\psi = \frac{b}{a}\left[\left(\frac{\delta u}{\delta h}\right)^2 + \left(\frac{\delta v}{\delta h}\right)^2 - \frac{g}{T}(\alpha_0 - \alpha) - \frac{\nu\rho}{b}\right]. \tag{2}$$

The eddy productivity generally varies with the height (h), in which case the integration of (1) offers great difficulties. However, we may then divide the air column into a number of layers and to each of them attribute a suitable constant value of ψ, thus simplifying the integration.

Now integrate (1) in the following case. Between the ground ($h=0$) and the height H the eddy productivity ψ is constant, positive and equal to ψ_0. For $h>H$ the eddy productivity is equal to another, negative, constant, $-\psi_1$. Thus we have to integrate the equation

$$\frac{\delta}{\delta h}\left[E\frac{\delta E}{\delta h}\right] + \psi_0 E = 0. \tag{3}$$

between the limits 0 and H.

We obtain, as previously shown,

$$E^2\left(\frac{\delta E}{\delta h}\right)^2 = \text{constant} - \frac{2\psi_0}{3}E^3. \tag{4}$$

At the ground $E=0$. The constant of integration obviously must be positive, since it is equal to the square of the loss of eddy energy at the surface. From (4) it is seen, that E increases more and more until it reaches a maximum value E_m at the height H_m. At this height

$$\frac{\delta E}{\delta h} = 0$$

and therefore

$$\text{Constant} = \frac{2\psi_o E_m^3}{3}.$$

Thus,

$$(5) \qquad E^2\left(\frac{\delta E}{\delta h}\right)^2 = \frac{2\psi_o}{3}\left[E_m^3 - E^3\right]$$

Substituting for E the expression

$$(6) \qquad E = zE_m$$

we obtain

$$z^2\left(\frac{\delta z}{\delta h}\right)^2 = \frac{2\psi_o}{3E_m}(1-z^3)$$

or, after integration,

$$(7) \qquad \int_0^z \frac{z\,dz}{\sqrt{1-z^3}} = \sqrt{\frac{2\psi_o}{3E_m}} \cdot h \qquad (h < H_m).$$

Between the constants E_m and H_m we have the relation

$$(8) \qquad q = \int_0^1 \frac{z\delta z}{\sqrt{1-z^3}} = \sqrt{\frac{2\psi_o}{3E_m}} \cdot H_m$$

or

$$(9) \qquad E_m = \frac{2\psi_o}{3q^2} \cdot H_m^2$$

Between H_m and H we have

$$(10) \qquad \int_z^1 \frac{z\,dz}{\sqrt{1-z^3}} = \sqrt{\frac{2\psi_o}{3E_m}}\,(h - H_m).$$

If we denote by E_1 the value of E for $h = H$, then

$$(11) \qquad q_1 = \int_{z_1}^1 \frac{z\,dz}{\sqrt{1-z^3}} = \sqrt{\frac{2\psi_o}{3E_m}}\,(H - H_m) \qquad \left(z_1 = \frac{E_1}{E_m}\right).$$

In the upper eddy consuming layer we have

$$(12) \qquad \frac{\delta}{\delta h}\left[E\frac{\delta E}{\delta h}\right] - \psi_1 E = O,$$

and, after integration,

$$(13) \qquad E = \frac{\psi_1}{6}(H_2 - h)^2,$$

where H_2 is the constant of integration. E and $\frac{\delta E}{\delta h}$ being continuous at the boundary between the two layers, we obtain

$$\psi_1 E_1^3 = \psi_o\left[E_m^3 - E_1^3\right]$$

or

$$(14) \qquad z_1 = \frac{E_1}{E_m} = \sqrt[3]{\frac{\psi_o}{\psi_o + \psi_1}}.$$

From

$$(15) \qquad E_1 = \frac{\psi_1}{6}\left[H_2 - H\right]^2$$

and (14) it follows that

$$(16) \qquad H_2 = H + \frac{2H}{q + q_1}\sqrt[6]{\frac{\psi_o^4}{(\psi_o + \psi_1)\psi_1^3}}.$$

From (9) and (15) it follows that

$$(17) \qquad H_m = \frac{q}{q + q_1} \cdot H.$$

The amount of eddy energy, which per unit time is dissipated at the ground, is equal to

$$(18) \qquad \left(aE\frac{\delta E}{\delta h}\right)_{h=o} = \frac{4a\psi_o^2}{q} \cdot \frac{H^3}{(q+q_1)^3}.$$

From this formula it is seen that the dissipation of eddy energy at the surface is independent of the nature of the ground. That may be approximately true in the case of pure convection but is doubtless wrong as soon as wind is blowing and the turbulence is partly of mechanical origin. This becomes obvious if we compare the values of eddy viscosity over a rough land surface and over sea.

However, the influence of the ground will make itself apparent in an indirect way. If we assume that the wind vector ($\mathfrak{v}$) does not vanish at the surface, then we get the following boundary condition in determining the mean wind distribution:

$$(19) \qquad \mathfrak{R} = c_m \cdot \left(\frac{\partial \mathfrak{v}}{\partial h}\right)_{h=o}.$$

The vector $\mathfrak{R}$, the tangential force between the wind and the ground, is a function of the surface wind $\mathfrak{v}_{h=o}$ and has probably the form

$$(20) \qquad |\,\mathfrak{R}\,| = \text{constant} \cdot |\,\mathfrak{v}_{h=o}\,|^2$$

The constant in (20) gives a measure of the roughness of the surface. The two conditions (19) and (20) have the following consequence: Over a rough surface there will be very little slipping and therefore a rapid increase of wind velocity with height. On the contrary, a smooth surface will admit a high degree of slipping. Thus the increase of wind with height will in this case be much less pronounced and restricted to a rather shallow layer. The eddy productivity, being proportional to the square of the increase of wind velocity with height, therefore has a high value over a continent but remains—for the same gradient wind—comparatively small over a smooth surface, for instance, the sea.

A numerical example has been computed and plotted in Figure 5, illustrating the integral obtained above. The height of the eddy producing layer has been chosen as 200 m. Assuming within this layer an average vertical increase of wind velocity of 2 m/sec per 100 m. and a lapse rate of 0.6° C. per 100 m., we obtain for the eddy productivity the value

$$\psi_o = 4 \cdot 10^{-4} - \frac{g}{T} \cdot 0.4 \cdot 10^{-4} \sim 2.6 \cdot 10^{-4}.$$

In the upper eddy consuming layer the wind velocity is constant. Thus we get

$$\psi_1 = \frac{g}{T} \cdot 0.4 \cdot 10^{-4} \sim 1.4 \cdot 10^{-4}.$$

From these numerical data we compute a maximum value of E, $4.3 \cdot 10^4$ $\frac{\text{ergs}}{\text{gram}}$, at the height 135 m. The eddy energy totally disappears 599 m. above ground.

Now let us compare our computed E curve with the observed conditions. The eddy energy (E) itself can not be directly measured, but it is possible from observations of the gustiness of wind to get a rough idea of the magnitude of E.

M. Robitzsch has given a table showing the most frequent gustiness amplitudes corresponding to different mean wind velocities (*6*). In the numerical example just given we have assumed a total increase in wind velocity from the ground upward of 4 m. p. s. Since the gradient velocity generally can be assumed to be twice the surface velocity, the latter would in this case be 4 m. p. s. For this average wind the gustiness amplitude is about 3.7 m. p. s. According to Robitzsch about 25 extreme values of the horizontal wind velocity occur per minute. This would correspond to a period of about 5 sec. We may then substitute for the real, turbulent wind a periodically changing horizontal velocity,

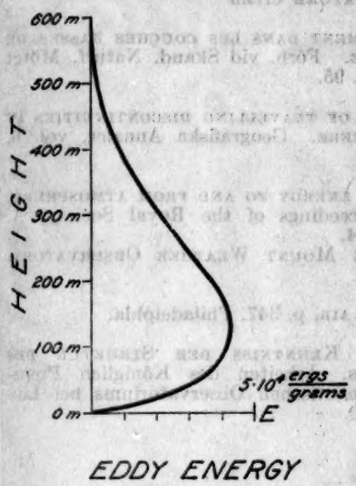


FIG. 5

$$v=\left(400+\frac{370}{2}\sin\frac{2\pi t}{5}\right)\frac{\text{cm}}{\text{sec}}.$$

If the vertical components of the eddy velocities are supposed to follow the same law, then the total eddy energy per unit mass must be equal to

$$E=\frac{3}{2}\cdot\frac{1}{2}\left(\frac{370}{2}\right)^2\cdot\frac{1}{5}\int_0^5\sin^2\frac{2\pi t}{5}\,dt=\frac{3}{160}(370)^2=2.6\cdot10^3\ \frac{\text{ergs}}{\text{gram}}.$$

Now, Robitzsch's data are based upon records from an instrument placed about 7 m. above ground. Our theoretical solution gives at the same height an E-value several times larger, $12.9\cdot10^3\ \frac{\text{ergs}}{\text{gram}}$. It must, however, be kept in mind, that the vertical change in E at these lower levels is so great that a comparison between theoretical and observed values for single points becomes extremely difficult.

Since, according to (I, 7), E and c_M are proportional, the computed curve also represents the variation of the eddy viscosity with height. It is seen, that in its general features this curve well agrees with Solberg's result and also with some curves for the vertical variation of c_M over the sea, which the author has calculated from certain pilot balloon observations [4] over the North Atlantic during the summers 1924 and 1925. (Fig. 6.) The curve marked s is made up from winds with a southerly component and should therefore represent a stable stratification. The u curve is computed from winds with a northerly component (air temperature below water temperature) and should thus be characteristic for an unstable stratification. The curve m was obtained from the entire material. It is seen that the s curve reaches a well-developed maximum already at 80 m. above sea level. In case of unstable stratification the eddy-producing layer must evidently be much deeper, since the eddy viscosity does not reach its maximum value within the lowest 200 m.

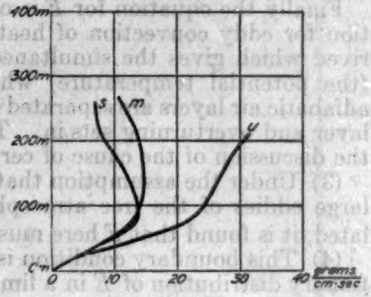


FIG. 6

In this connection it may be of interest to discuss the order of magnitude of the constant a. Denote it

$$magn\ a$$

We have

$$a=\frac{c_M}{E}.$$

According to the example just given and to measurements of the gustiness we have

$$magn\ E=10^4.$$

On the other hand

$$magn\ c_M=10^1\text{ to }10^2.$$

Thus

$$magn\ a=\frac{magn\ c_M}{magn\ E}=\frac{10^1\text{ to }10^2}{10^4}=10^{-3}\text{ to }10^{-2}.$$

Assume for a the value 10^{-3}. We then find from Figure 5 a maximum value for c_M of 43 $\frac{\text{grams}}{\text{cm}\times\text{sec}}$, which is in good agreement with observations.

The constant a being known we are able to calculate numerically the diffusion velocities derived in section II. It is seen that they all fall within the limits which could be drawn *a priori*. Closer comparison is impossible as long as reliable measurements of the eddy diffusion are wanting.

SUMMARY

(1) Starting from an energy equation given by L. F. Richardson, the author derives a differential equation for the atmospheric eddy energy per unit mass (E). The assumption is made that the diffusion of eddies follows the law

$$-c_E\frac{\partial E}{\partial h}\qquad(h=\text{the height above ground}),$$

and that the coefficient c_E, as well as the coefficients of eddy viscosity and eddy convectivity, are proportional to E. The conception *eddy productivity* (ψ) is introduced, and it is shown that the production of eddy energy per unit mass and time is equal to $\psi.E$.

(2) Some integrals to the equation for E are given for the case of an unlimited atmosphere at rest. First, the special stationary distribution of E is derived, which occurs when a narrow eddy-producing layer is surrounded by two eddy-consuming layers. It is shown that even a comparatively high lapse rate of 0.7° C./100 m. is very effective in suppressing eddy diffusion currents.

Furthermore, the diffusion of an initially limited eddy supply during different temperature conditions is studied. It is found that in case of stable stratification

[4] These data will be published in Geografiska Annaler, Stockholm.

the diffusion will never reach beyond certain limits. During unstable stratification the eddies travel with increasing velocity toward infinity.

Finally the equation for E is combined with the equation for eddy convection of heat, and an integral is derived which gives the simultaneous changes in E and θ (the potential temperature) when two infinitely thick adiabatic air layers are separated by a thin superadiabatic layer and overturning sets in. The solution is applied to the discussion of the cause of certain thunderstorms.

(3) Under the assumption that close to the ground the large eddies of the free atmosphere are rapidly annihilated, it is found that E here must be proportional to $\sqrt{h}$.

(4) This boundary condition is used for deriving a stationary distribution of E in a limited atmosphere. Since E and the eddy viscosity are proportional, the resulting curve for E can be compared with known values of the variation of eddy viscosity with height and fair agreement is found.

ACKNOWLEDGMENTS

In carrying out this study the author has had the benefit of numerous suggestions from Prof. W. J. Humphreys and Mr. E. A. Woolard of the United States Weather Bureau, as well as from Dr. H. U. Sverdrup, Bergen, Norway, for which he wishes to express his sincere gratitude. Thanks are also due to Dr. B. M. Varney, of the Weather Bureau, who has carefully revised the manuscript from a linguistic point of view.

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A FURTHER STUDY OF EFFECTIVE RAINFALL

By J. F. VOORHEES

[Weather Bureau, Honolulu, Hawaii]

With every new attempt to find a correlation between rainfall and the growth or yield of some crop one is more deeply impressed with the need for further information concerning effective rainfall and the factors which determine how large a proportion of a given amount of precipitation may be utilized. The problem has been attacked, directly or indirectly, by many investigators and from several angles, but we still have no information that is definite enough to make a satisfactory basis for a correlation between precipitation and yield. Yet we get apparently high correlations in many instances. For example, the correlation coefficient between June rainfall and the yield of oats at Akron, Colo., as calculated by Mr. Mattice, of this bureau, is $+0.91 \pm 0.03$. This is thirty times the probable error but when we try to discover just what this high correlation is good for we find it worth very little indeed. If yields are calculated by the least square formula $y' = bx + a$, the standard deviation of $y - y'$ is found to be 59 per cent less than the standard deviation of y. But the departure of y' from y was 75 per cent of the mean value of y one-fifth of the time, which would make our calculated yield little if any better than a good guess, and practically worthless for predicting yields.

The amount of water used in making a crop of corn has been so often determined and the results are in such close agreement that we may feel reasonably certain that each pound of dry matter in a corn plant will have used from 250 to 400 pounds of water, depending on the fertility of the soil. The larger amount will have been used on the poorer soil. Thus, after it has been harvested and weighed, we can tell about how much water a given crop has used.

It has been shown also that the application of manure or of a straw mulch will increase the moisture-holding capacity of most soils, and measurements have been made of the amount of water available in the upper layers of various soils when saturated. Here, again, we have nothing on which a forecast could be based.

In a previous paper (this REVIEW, February, 1925) the writer attempted to determine the amount of effective rainfall by a process of elimination. First, there was deducted a minimum amount which it was assumed would be lost by immediate evaporation after each rain. Second there was deducted the amount discharged in the streams, as evidently having been of no benefit, whether or not it might have been beneficial under different conditions.

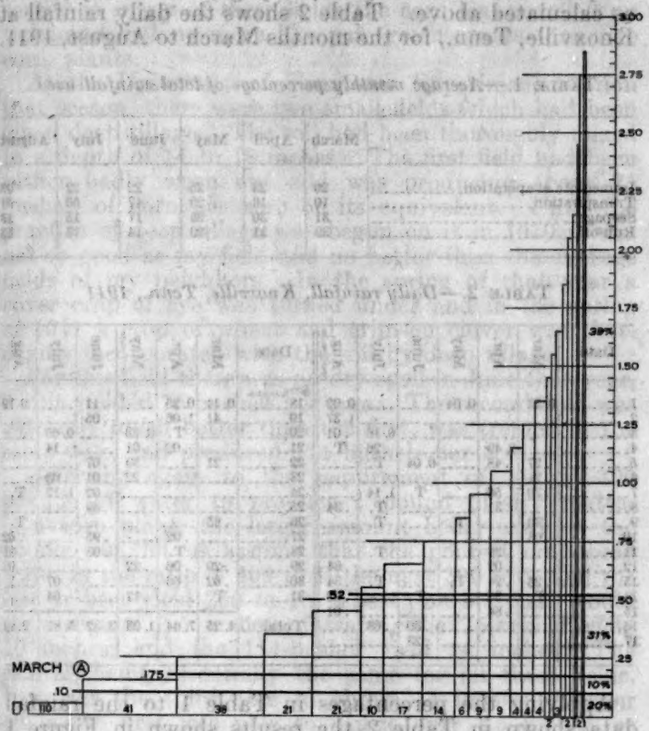
This left an amount which presumably escaped, either by transpiration or evaporation or both. It was suggested that under favorable conditions a growing crop might utilize the major part of this residue and that it might also be able to reduce the portion lost in the streams.

It is now proposed to try to throw a little more light on the question of effective rainfall by considering a particular case.

We first present the charts, A to F, showing for Knoxville for each of the months March to August, inclusive, the total number of days in the 27 years of record which have had rainfalls of the indicated amounts. The abscissæ represent days and the ordinates rainfall in inches and tenths. Each column represents the rainfall for one day and the total of the figures at the bottom gives all the rainy days for the given month for the 27 years.

The heavy horizontal line at the 0.1-inch mark cuts off of the bottom the amount probably lost by immediate evaporation. In March this amounts to 20 per cent of the total rainfall. Then, since the previous study showed that 70 per cent of the March rainfall appeared in the river, a line was drawn at a point cutting off 30 per cent from the bottom and leaving the 70 per cent which appeared in the river above. The part between these two lines, or 10 per cent of the total, is the amount normally used in transpiration or lost later by evaporation

Next, it seemed worth while to make some distinction between surface run-off and water reaching the river by seepage. It was assumed that all water above the minimum stage of the river, for a given month, was due to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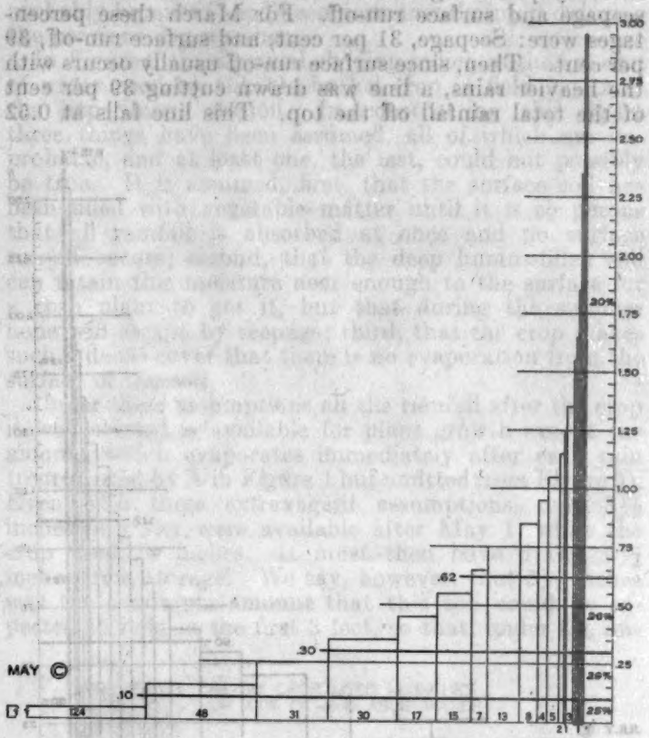
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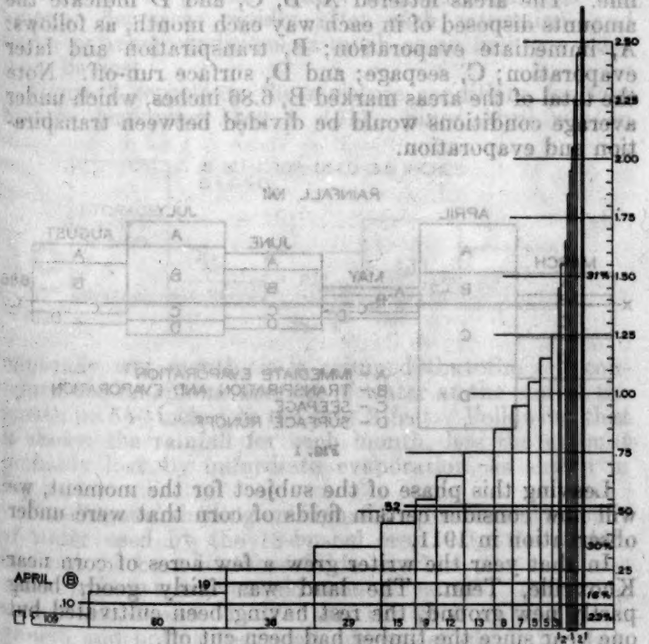
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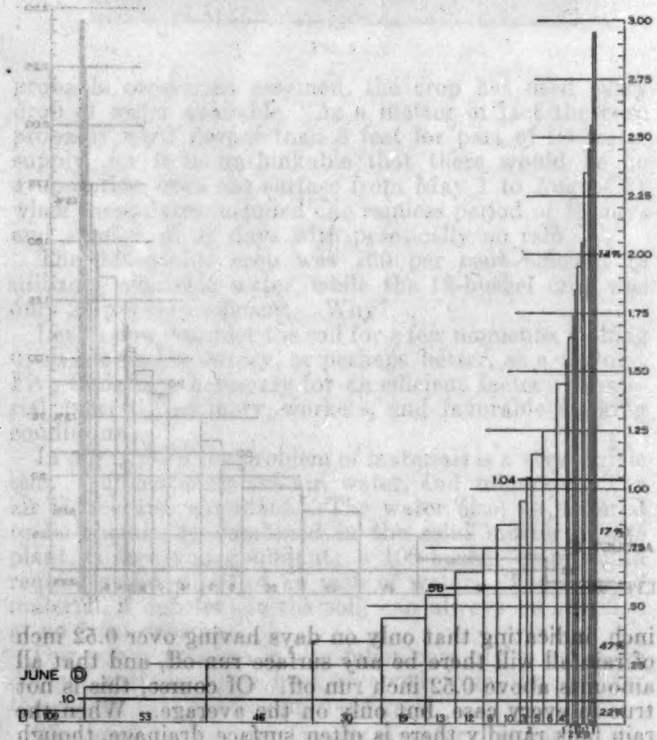
JUNE D
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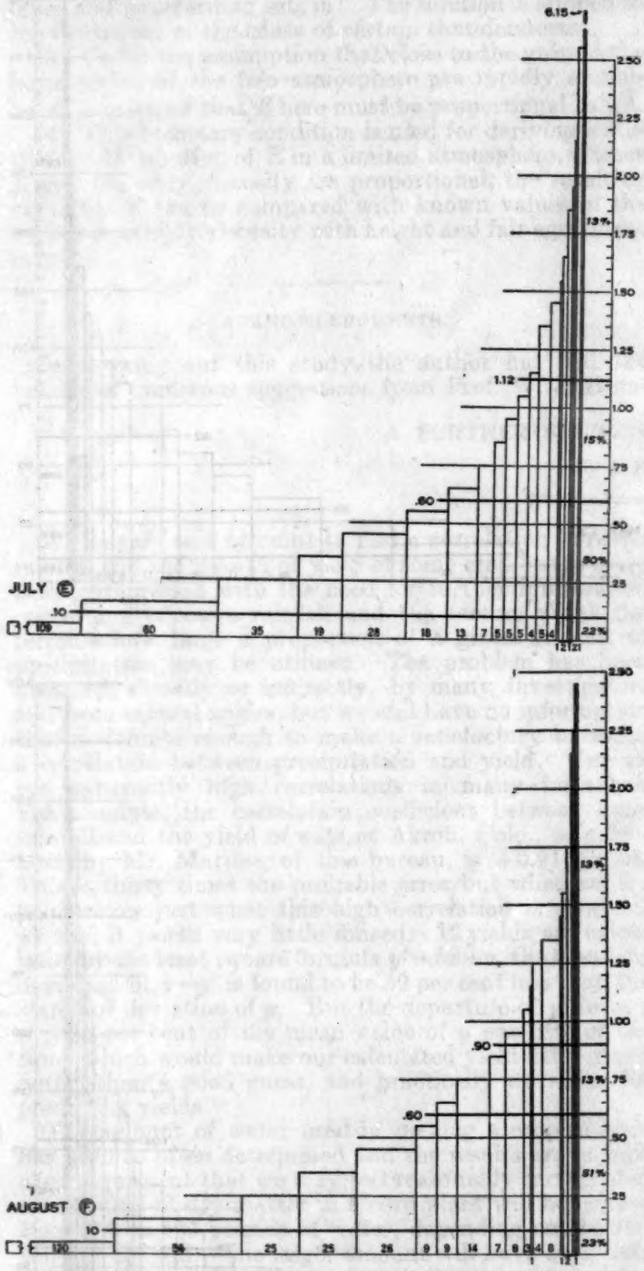
surface run-off and the rest to seepage. Using 21 years' record of rainfall, river stages, and discharge data, monthly percentages of total rainfall were obtained for seepage and surface run-off. For March these percentages were: Seepage, 31 per cent, and surface run-off, 39 per cent. Then, since surface run-off usually occurs with the heavier rains, a line was drawn cutting 39 per cent of the total rainfall off the top. This line falls at 0.52



inch, indicating that only on days having over 0.52 inch of rainfall will there be any surface run-off, and that all amounts above 0.52 inch run off. Of course, this is not true in every case, but only on the average. When the rain falls rapidly there is often surface drainage, though the total amount of precipitation may be less than 0.52 inch; on the other hand, greater amounts falling slowly, when soil moisture is depleted, may all soak in.

Table 1 shows for the months March to August the average percentage of total rainfall lost by immediate evaporation, surface run-off, seepage, and transpiration, as calculated above. Table 2 shows the daily rainfall at Knoxville, Tenn., for the months March to August, 1911.

TABLE 1.—*Average monthly percentage of total rainfall used*

	March	April	May	June	July	August
Immediate evaporation	20	23	25	22	22	23
Transpiration	10	16	29	47	50	51
Seepage	31	30	26	17	15	13
Run-off	39	31	20	14	13	13

TABLE 2.—*Daily rainfall, Knoxville, Tenn., 1911*

Date	Mar.	Apr.	May	June	July	Aug.	Date	Mar.	Apr.	May	June	July	Aug.
1	0.33	-----	0.04	-----	-----	0.02	18	0.11	0.25	-----	.11	-----	0.19
2	-----	-----	-----	-----	-----	1.37	19	.41	1.06	-----	.06	-----	-----
3	-----	-----	-----	-----	0.18	.01	20	-----	T.	0.23	-----	0.65	-----
4	-----	2.49	-----	-----	.26	T.	21	-----	.02	.01	-----	.14	-----
5	.27	.48	-----	0.04	T.	-----	22	.21	-----	.39	.07	-----	-----
6	.21	-----	-----	-----	-----	-----	23	-----	-----	.22	.01	.03	-----
7	.70	.56	-----	T.	1.14	-----	24	-----	-----	-----	.02	1.12	T.
8	-----	.31	-----	-----	T.	.34	25	-----	-----	-----	.89	-----	-----
9	.30	-----	T.	-----	T.	-----	26	.85	-----	-----	-----	-----	T.
10	.03	-----	-----	-----	-----	-----	27	-----	.02	-----	.95	-----	.02
11	-----	.29	-----	-----	T.	-----	28	-----	T.	-----	.05	-----	.01
12	-----	.02	-----	-----	-----	.64	29	.29	.06	.22	-----	-----	.02
13	.26	.24	T.	-----	T.	.34	30	.02	.66	-----	-----	.07	-----
14	T.	.36	-----	T.	-----	.02	31	T.	-----	.12	-----	.04	-----
15	-----	.84	-----	-----	-----	.01							
16	-----	-----	-----	.30	.68	-----	Total	4.25	7.64	1.23	3.32	5.87	2.99
17	-----	-----	-----	.23	-----	-----							

Applying the percentages in Table 1 to the rainfall data shown in Table 2 the results shown in Figure 1 were obtained. In this diagram the portion of the rainfall represented by the total discharge of the streams is below the line *xy*, while the portion normally used by transpiration or lost by evaporation appears above that line. The areas lettered A, B, C, and D indicate the amounts disposed of in each way each month, as follows: A, immediate evaporation; B, transpiration and later evaporation; C, seepage; and D, surface run-off. Note the total of the areas marked B, 6.86 inches, which under average conditions would be divided between transpiration and evaporation.

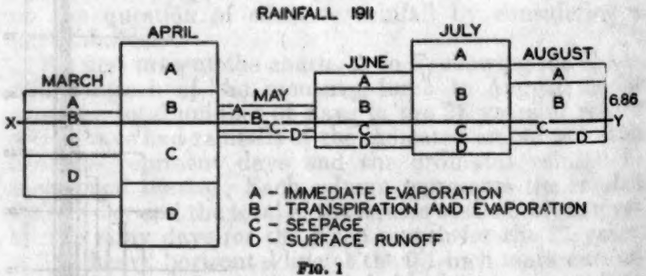


FIG. 1

Leaving this phase of the subject for the moment, we will now consider certain fields of corn that were under observation in 1911.

In that year the writer grew a few acres of corn near Knoxville, Tenn. The land was fairly good, being partly new ground, the rest having been cultivated but one year since the timber had been cut off.

The crop started off beautifully, but dry weather during May and the first half of June injured it badly and the final yield was about 18 bushels per acre. In this field the soil was broken about 6 inches deep, which is referred to as shallow tillage. My neighbors, also

using shallow tillage, and on a great variety of soils, obtained practically the same results that I did. Just before the rain that came in the middle of June I observed in many of these fields the corn leaves rolled up tight and looking more like pale green spears than like corn plants.

At the University of Tennessee Experiment Station that season, there were two small fields which had been given deep tillage. The soil had been thoroughly mixed to a depth of 14 to 18 inches. The first field had been rather badly worn out and was producing about 25 bushels of corn per acre or its equivalent. Until the practice of deep tillage was begun on it in 1910 it was not so good as my field and no better than the average fields of my neighbors. In the spring of that year a cover crop of rye was turned under and in the spring of 1911 a crop of wheat and crimson clover was thoroughly incorporated with the soil by deep tillage.

For this field there was no dry spell in June that year, and it yielded 75 bushels per acre. The second field was naturally much better than the first, was treated in the same way, and produced 114 bushels per acre.

Referring again to the requirement of 250 to 400 pounds of water to produce 1 pound of dry matter in a corn plant, the larger amount being used on the poorer soil, let us assume that the poorest crop used water in the ratio of 400 to 1, the next 300 to 1, and the last or best yield 250 to 1. The 18-bushel yield would then require 3.5 inches of water, the 75-bushel yield 10 inches, and the 114-bushel yield 14 inches. The rainfall being essentially the same for all these fields, how was the third able to obtain 14 inches of water while the first was able to utilize only 3.5 inches, or one-fourth as much?

These soils would probably be classed as silt loams. When saturated they might be expected to contain in the first 3 feet not to exceed 5½ inches of water available for the use of plants. Under average conditions this amount decreases rapidly after each saturation, and under extreme conditions as much as an inch per week may be lost.

Figure 2 represents the moisture conditions for four months beginning May 1, 1911. Since April was an

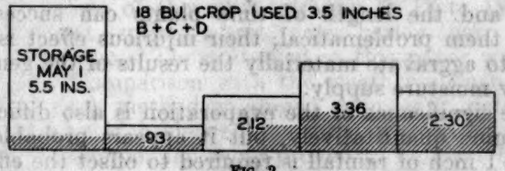


FIG. 2

unusually wet month, it is assumed that the soil contained the maximum amount of water at the end of the month or 5½ inches in the first 3 feet. Following that is shown the rainfall for each month, less the amount probably lost by immediate evaporation, as shown in Figure 1.

The diagonal shading on Figure 2 indicates the amount of water used by the 18-bushel crop. By the middle of June the corn in those fields in which the crop was suffering for water averaged about 5 feet tall. Assuming that it would take 1 inch of water to produce that much growth and noting the small amount available in May, we find that the crop drew perhaps 0.5 inch out of storage. If there had been no other losses this would leave more than 5 inches still available. As a matter of fact, however, there was practically no more available moisture in the soil, for the corn stopped growing and twisted its leaves into spears to fight off death as long as possible. From the middle of June on the supply of moisture was rather large, but the crop was not able to use it all, probably because it had been permanently injured during the previous dry weather.

In Figure 3 the diagonal shading indicates the amount of water used by the 114-bushel crop in field No. 2 at the experiment station. In constructing this figure three things have been assumed, all of which are improbable, and at least one, the last, could not possibly be true. It is assumed, first, that the surface soil has been filled with vegetable matter until it is so porous that all rainfall is absorbed at once and no surface run-off occurs; second, that the deep humus-filled soil can retain this moisture near enough to the surface for a corn plant to get it, but that during the summer none will escape by seepage; third, that the crop makes such a dense cover that there is no evaporation from the surface of the soil.

Under these assumptions all the rainfall after the crop is well started is available for plant growth except the amount which evaporates immediately after each rain (represented by A in Figure 1 but omitted from Figure 3). Even with these extravagant assumptions, only 8½ inches of water were available after May 1, while the crop used 14 inches. It must then have drawn 5½ inches from storage. We say, however, that 5½ inches was the maximum amount that this soil could be expected to hold in the first 3 feet, so that, under the im-

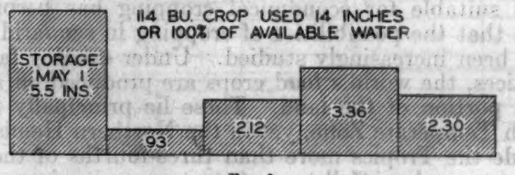


FIG. 3

probable conditions assumed, the crop has used every drop of water available. As a matter of fact the corn probably went deeper than 3 feet for part of its water supply, for it is unthinkable that there would be no evaporation from the surface from May 1 to August 31 when these dates included one rainless period of 18 days and another of 23 days with practically no rain.

The 114-bushel crop was 100 per cent efficient in utilizing available water, while the 18-bushel crop was only 25 per cent efficient. Why?

Let us now consider the soil for a few moments, looking upon it as a laboratory, or perhaps better, as a factory. Five things are necessary for an efficient factory—material, power, machinery, workers, and favorable working conditions.

In our factory the problem of materials is a very simple one. Our materials are air, water, and minerals. The air is free and abundant. The water also, as material to be chemically combined in the solid matter of the plant, is free and abundant; a 100-bushel crop would require perhaps 0.04 of an inch of water. The mineral material, if deficient in the soil, can always be supplied at no great expense.

Our power problem is also taken care of for us, as we depend entirely upon heat received from the sun for the energy that makes our crops grow.

The machinery of our factory is water. It carries the materials dissolved in the soil up into the leaves for digestion and elaboration and thence throughout the plant to build tissue. The quantity of water employed

as machinery is probably three hundred times that used as material, and it is here that deficiencies are likely to occur. A crop of 100 bushels of corn per acre will probably require at least 12 inches of water. In the more humid climates a greater amount than this is usually received during the growing season of corn, but the supply is irregular and there are often periods of deficiency of available water. Except where irrigation is possible, the quantity received and the time of its receipt are wholly beyond our control.

The worker in our factory is life, in the plant itself and in the soil bacteria that prepare food for the plant. We can in some cases inoculate the soil with the right kind of bacteria, but beyond that point we are helpless except as we come to the fifth requirement for a factory, namely, favorable working conditions.

Here our opportunity for effective work begins—and ends. We have free material, free power, free machinery, free workers, and the only thing we can do to increase production to any great extent is to improve the working conditions in the soil Ideal conditions would include an optimum supply of water, a well-aerated soil, plenty of food materials, and sufficient heat. It would seem, if we may judge by results, that in the field producing 114 bushels per acre these conditions had been met as far as was humanly possible.

Two things were done in this field that were not done in the 18-bushel field. The soil was stirred to a greater depth and a very large amount of vegetable matter was added. Other experiments have shown that deep tillage without extra vegetable matter is of little or no value, so that the increased yield in this case must have been due to one of two things. Either the abundant supply of humus was entirely responsible, or, in combination with deep tillage, it furnished conditions favoring the highest possible conservation of the water supply, thus stimulating the living workers to maximum activity. Whether or not the deep tillage was of any value remains to be determined by further experiment.

Finally, it appears that effective rainfall is not a function of total rainfall (except when the latter is the limiting factor), but depends entirely upon the condition of the soil and the capacity of the crop for utilizing water. If one were to offer a practical suggestion based on this study it would be this: The addition of what would ordinarily be considered an excessive amount of vegetable matter to the soil might be a very profitable farm practice.

THE WEATHER INFLUENCE ON CROP PRODUCTION IN REGIONS OF SCANTY RAINFALL

By W. A. MATTICE

[Weather Bureau, Washington]

In recent years the surplus of Temperate Zone humid lands suitable for economical cropping has become so small that the possibilities of cropping in semiarid lands have been increasingly studied. Under existing farming practices, the world's food crops are produced on a very small portion of the land. These lie principally in the North Temperate Zone, yet in the Northern Hemisphere outside the Tropics more than three-fourths of the land has an annual rainfall too scanty to permit of successful farming by ordinary methods.

Under such conditions rainfall has a significance not attained in humid regions, because of the fact that at best the moisture present is rarely of a some-to-spare quantity, and what may be termed an average year has barely enough for crops to thrive.

A recent Department of Agriculture Bulletin, No. 1304,[1] entitled "Crop rotation and cultural methods at the Akron, Colo., Field Station," prepared by the Office of Dry-Land Investigations, Bureau of Plant Industry, contains much valuable information relative to crop production in that typical semiarid section of the United States, and a study of the data contained in it brings out many interesting facts as to the weather influence on yields.

In dry-land farming the retention of moisture in the soil is of primary importance, and consequently the relative humidity and the closely associated phenomena of evaporation afford a good index for studying the general effects of weather on crops. Statistical correlations show also that, so far as rainfall is concerned, the amount received during critical periods of growth for the several crops is of much greater importance than the annual amount, notwithstanding a statement in the bulletin above referred to that the greatest single factor in crop production is the amount of annual precipitation. Correlations show that several other factors give much higher coefficients than the annual amount of precipitation.

[1] This bulletin deals entirely with the difference in yields under the various cultural methods and merely touches on the weather effect. The yield data from this bulletin serve as a basis for the correlation studies herein presented.

The minimum amount of precipitation necessary for successful farming by ordinary methods is generally agreed to be between 15 and 20 inches. The Akron station has an average annual amount of 17.95 inches, but this is an average based on only 15 years. More than half of the years had less than this, sometimes reaching as low as 13.44 inches. Although the seasonal distribution of precipitation is in general more or less favorable for crop production, there were years when the amount of moisture received was insufficient to maintain plant growth, and 67 per cent of them had precipitation below normal.

There also occur in this region rather brief droughts which would not appear in a table of monthly totals. While the damage caused by these is difficult to determine and the length of time plants can successfully resist them problematical, their injurious effect is sufficient to aggravate materially the results of the generally scanty moisture supply.

The significance of the evaporation is also difficult to determine quantitatively, but it appears probable that about 1 inch of rainfall is required to offset the effect of 5 or 6 inches of free water-surface evaporation. Griffith Taylor, of the University of Sydney, Australia, found that about 5 inches of evaporation was equivalent to 1 inch of rainfall in Australia (*1*). If this ratio holds true for the United States, the effective rainfall for the summer at Akron, because of the relatively high rate of evaporation, is reduced on the average to about 5 inches.

The Akron, Colo., field station was established in 1907 and the first crops were grown in 1908; the rotations were begun in 1909. The soil at the station is typical of the so-called hard land of that region, and the climate conforms to the general conditions prevailing in the drier parts of the surrounding Great Plains.

Precipitation for the 16 years of record averaged 17.95 inches annually, with an average April to September rainfall of 13.69 inches. The latter is about 76 per cent of the annual, with the greatest monthly amounts occurring from April to August. The temperature is

noticeably affected by the proximity of the mountains, the frost-free season, averaging 140 days, May 12–September 29, being considerably shorter than for lower elevations farther east.

Evaporation measurements were made from April to September, inclusive. The equipment consisted of an open tank 6 feet in diameter and 2 feet deep, sunk to a depth of 20 inches in the ground, with the water level maintained at about the surface of the ground. The average seasonal evaporation is about 42 inches, or over twice the average annual precipitation and nearly three times the amount during the warm season.

In this region, where the amount of moisture received borders on the minimum needed to support cultivated crops, the question of evaporation must necessarily play an important part. The rate of evaporation, however, depends on so many factors that an adequate determination of the amount of moisture lost through this means is extremely difficult to determine. Evaporation from year to year from a free water surface, however, indicates the relative loss from the soil for different years, hence measurements that have been continuous at a given locality and made with the same instruments are comparable when applied to crop yields. The fact that the rate of evaporation correlates closely with the yields of some of the crops will be shown later.

The methods employed in this study to obtain the correlation coefficient follow those used by Smith (*2*) and Wallace (*3*). The first is probably familiar to most readers. Wallace's method supplies means of obtaining a multiple correlation using any number of factors; the maximum employed in this paper is five. The preparations for making the correlations are very simple—the departures from the average yield of the various crops for the period are compared with the various departures of the weather elements. As there are only 15 years of record in this case, an agreement of 12 or more of the departures seemed necessary for obtaining a coefficient enough larger than the probable error to be of value. This was verified to a large extent in the actual working out of the correlations, although exceptions were found where an agreement or disagreement of only 10 or 11 gave a useful value for *r*.

The crops grown at this station, each by various methods, some of them by as many as 13 to 18, were winter wheat, spring wheat, oats, barley, corn, kafir, milo, and sorgo. Those studied in this paper were the first five. Comparison with the weather elements was made for each method employed in order to determine the method which showed the greatest relation to the weather. Summer fallowing proved to be most baffling but the conclusion was finally reached that the elements which entered into the variations of yield in this case were so varied that any attempt to deal with them all would be beyond the scope of the available data.

The wide variations in the yields of the various crops are very significant—they indicate that about two-thirds of the time the crop is below "normal." The comparatively large crops for one-third of the time raise the general average of the period, so that no idea of the most probable yield is obtained. Thus, if one expects to grow oats in this region without any means of regulating the amount of water for the crop, only one-third of the years will produce a crop worth marketing, as the average yield is so low.

WINTER WHEAT

Winter wheat in Colorado is grown mainly in the northeastern section, where rainfall averages 15 to 20 inches a year, of which about 75 per cent occurs during the six months April to September.

This crop was sown at Akron about September 21, on the average, and was harvested about the middle of July. Table 1 shows the yields of winter wheat (bushels per acre) under eight cropping methods, together with the correlation coefficients between the respective yields and five weather elements.

TABLE 1.—*Winter-wheat yields and correlations*

Method	Yields	Correlation with—				
		June rainfall	Fall rainfall	December mean temperature	June evaporation	Seasonal evaporation
1. Late fall plowing	9.1	+.82±.06	+.68±.09	−.70±.09	−.69±.09	−.65±.10
2. Early fall plowing	10.5	+.76±.07	+.66±.10	−.57±.12	−.54±.13	−.44±.14
3. Subsoiling	9.2	+.83±.05	+.74±.08	−.66±.10	−.69±.09	−.58±.12
4. Listing	10.1	+.72±.08	+.52±.13	−.57±.12	−.60±.11	−.49±.14
5. Disking in rotation with corn	13.5	+.71±.09	+.56±.12	−.66±.10	−.64±.10	−.60±.11
6. Green manuring with rye	14.2	+.62±.11	+.44±.14	−.55±.12	−.57±.12	−.49±.14
7. Green manuring with peas	10.8	+.66±.10	+.59±.11	−.60±.11	−.57±.12	−.43±.14
8. Summer fallowing	19.1	+.52±.13	+.38±.15	−.45±.14	−.49±.14	−.32±.16
Mean	------	+.70±.09	+.57±.12	−.60±.11	−.60±.11	−.50±.13

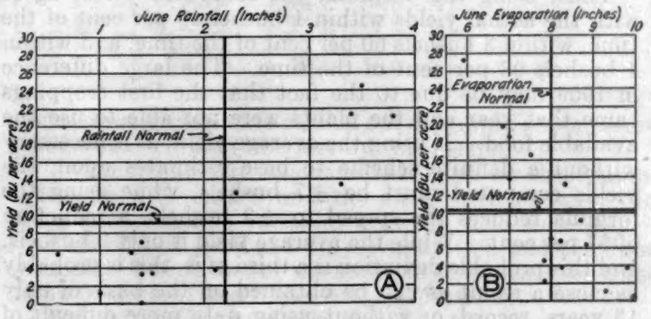


FIG. 1, *A*.—June rainfall and yield of winter wheat 3. *B*.—June evaporation and average spring wheat yield

That the wheat plant must have an abundance of moisture at the time of heading is shown by the occurrence of the highest correlation in the case of yield versus rainfall of the June just preceding harvest. The importance of fall precipitation to development of the root system is also suggested, though it is less than that of the June precipitation. With green manuring and fallowing, June rainfall is not so important. The negative correlations between yield and December mean temperature and June evaporation are most marked in the case of early fall plowing. Seasonal evaporation apparently is of little consequence. From these facts and from figure 1, *A*, we conclude that June precipitation is the dominating factor, and that when it is above normal the winter-wheat crop will also be above normal. The spread of the dots, however, indicates that there are some other factors not taken into account.

The greatest effectiveness of fall precipitation occurs when subsoiling is practiced, enabling the lower soil layers better to retain the autumn rainfall and thus to aid in establishing the good root system so necessary for best growth. June rainfall is more effective with subsoiling and early fall plowing than with any of the other methods—again probably a case of making soil moisture more easily available to the plants.

A multiple correlation was worked out for method 3, or subsoiling, as this seemed to offer the best relation to the weather. The elements used were: (A) June precipitation of the same year; (B) fall precipitation of the year

previous, or immediately after planting; (C) the December mean temperature of the previous year; and (D) the June evaporation. The resulting coefficient was 0.94 ± 0.02. This indicates a very good relation between the various elements and the crop, and the regression equation was found:

$$\overline{X} = 1.8A + 2.9B - 0.6C - 1.1D + 33.4$$

Substituting the values of the elements in this equation, we get for the computed yields (bushels per acre):

Year	Computed yields	Actual yields	Difference
1909	25	13	12
1910	11	7	4
1911	3	3	0
1912	18	21	3
1913	7	3	4
1914	20	24	4
1915	21	21	0
1916	4	4	0
1917	9	6	3
1918	0	1	1
1919	11	12	1
1920	18	15	3
1921	5	6	1
1922	4	0	4
1923	5	1	4

Thus, using this formula, the computed yields agree with the actual yields within 1 bushel 40 per cent of the time, within 3 bushels 60 per cent of the time, and within 4 bushels 93 per cent of the time. The large difference in 1909 may be due to the fact that the first croppings came that year and the plants were not able to use the available food. If using the average yield, as is necessary without a definite scheme to base estimates upon, the yields computed must be ± 7 bushels, while using the formula reduces the spread to ± 3 bushels, a reduction of 57 per cent. While the average yield is only 9 bushels, and this probable deviation is a third of it, this is probably as close a result as can be obtained on the basis of only 15 years' record, or without using data more difficult of access.

SPRING WHEAT

The average date of planting spring wheat at Akron was March 29 and the average time of harvesting about the last of July. Table 2 shows the yields of spring wheat (bushels per acre) under 13 cropping methods, together with the correlation coefficients between the respective yields and five weather elements.

TABLE 2.—*Spring wheat yields and correlations*

Methods	Yields	Correlation with—				
		Seasonal evaporation	June evaporation	December mean temperature	June rainfall	May and June rainfall
1. Fall plowed in rotation with corn	11.5	−.73±.08	−.76±.07	−.76±.07	+.69±.09	+.72±.08
2. Fall plowed in rotation with oats	8.8	−.72±.08	−.78±.07	−.65±.10	+.78±.07	+.75±.07
3. Fall plowed continuous wheat	8.1	−.74±.08	−.76±.07	−.71±.08	+.71±.08	+.81±.06
4. Spring plowed in rotation with corn	12.6	−.77±.07	−.81±.06	−.81±.06	+.76±.07	+.73±.08
5. Spring plowed in rotation with oats	10.1	−.76±.07	−.80±.06	−.64±.10	+.74±.08	+.83±.05
6. Spring plowed continuous wheat	11.5	−.70±.09	−.75±.07	−.74±.08	+.67±.10	+.78±.07
7. Subsoiled	7.3	−.78±.07	−.79±.06	−.72±.08	+.76±.07	+.77±.07
8. Listed	8.3	−.77±.07	−.80±.06	−.72±.08	+.74±.08	+.81±.06
9. Disked in rotation with corn	9.6	−.77±.07	−.83±.05	−.76±.07	+.82±.06	+.70±.09
10. Green manured with rye	10.4	−.73±.08	−.76±.07	−.78±.07	+.72±.08	+.74±.08
11. Green manured with peas	8.8	−.76±.07	−.78±.07	−.74±.08	+.75±.08	+.70±.09
12. Green manured with sweet clover	9.2	−.72±.08	−.72±.08	−.65±.10	+.59±.11	+.83±.05
13. Summer fallowed	13.2	−.74±.08	−.79±.06	−.67±.10	+.78±.07	+.73±.08
Mean		−.74±.08	−.78±.07	−.72±.08	+.73±.08	+.76±.07

The greatest single factor in the production of spring wheat appears to be the amount of June evaporation, as shown in Table 2. The amount of spring rainfall has also a very large effect on the yield of spring wheat, probably for the same reason that winter wheat needed rain soon after seeding in order to insure a good root system. The methods which show the greatest relation to June evaporation are disking in rotation with corn and spring plowing in rotation with corn. Evidently the amount of June evaporation has a very decided effect upon the yield. When evaporation was above normal the yield was materially reduced, as indicated by Figure 1, *B*, which shows the relation between June evaporation and the yields of spring wheat, averages of all methods being used in this case.

When the June evaporation was below normal, the yield was above normal five years out of seven, or 70 per cent of the time; and when June evaporation was normal or above, the yield was below normal seven years in eight, or 88 per cent of the time.

As the method of disking in rotation with corn seemed to offer the highest general correlation with the weather, a multiple correlation for this crop and the five elements was worked out. This gave the extremely high coefficient of 0.97 ± 0.01. The regression equation for these elements is:

$$\overline{X} = -0.3A - 0.7B + 0.4C + 0.7D - 0.2E + 37$$

The values of the yields (bushels per acre) computed from this equation are:

Year	Computed yields	Actual yields	Difference
1909	16	15	1
1910	11	13	2
1911	2	1	1
1912	19	15	4
1913	3	6	3
1914	17	12	5
1915	28	21	7
1916	6	6	0
1917	10	14	4
1918	0	6	6
1919	4	6	2
1920	20	13	7
1921	2	4	2
1922	4	6	2
1923	4	7	3

These values give an average deviation from the true yields of 3 bushels. Using the average yield to estimate the crop would not give on the average results closer than 7 bushels, thus a reduction of 4 bushels, or 57 per cent, is effected by the computation. This is probably as close as can be made with the available data.

Figure 2 shows graphically the computed and actual yields. It will be seen from it that the greatest deviations occur in years of greatest yields. It is very evident that there is some variable not included in the data which materially affects the yield, although it would not affect the value of the correlation coefficient to any great extent.

One point of interest in connection with correlations of spring wheat shown in Table 2 is suggested. Why the December mean temperature of the previous year gave a high value for the correlation coefficient is not readily apparent, and in order to verify this as much as possible a correlation between the December mean temperature and the yield of spring wheat was made for the State of North Dakota. The value of r obtained from this was 0.04 ± 0.09, which indicated no relation. For northwestern Kansas, using only one station, as the

spring-wheat region is fairly limited there, a value of −0.40 was obtained. This latter value indicates a slight relation between the December mean temperature and the spring wheat yields, although there is no relation in North Dakota. The results at Akron might, of course, be entirely accidental, which seems the logical explanation.

OATS

Oats were sown on the average on April 3 and were harvested about the last of July. Table 3 shows the yields of oats (bushels per acre) under 18 cropping methods, together with the correlation coefficients between the respective yields and six weather elements.

TABLE 3.—*Oat yields and correlations*

Methods	Yields	Correlations with—					
		June mean temperature	June to August mean temperature	June rainfall	February to April relative humidity	June and July evaporation	June evaporation
1. Fall plowed in rotation with wheat	19.8	−0.58±0.12	−0.66±0.10	+0.65±0.10	+0.52±0.13	−0.78±0.07	−0.70±0.09
2. Fall plowed in rotation with oats	21.4	−.65±.10	−.77±.07	+.68±.09	+.74±.08	−.70±.09	−.64±.10
3. Fall plowed in rotation with barley	22.0	−.63±.10	−.72±.08	+.72±.08	+.49±.14	−.72±.08	−.70±.09
4. Spring plowed rotation with wheat	22.7	.58±.12	−.71±.08	+.66±.10	+.76±.07	−.82±.06	−.74±.08
5. Spring plowed rotation with oats	22.6	−.72±.08	−.77±.07	+.66±.10	+.76±.07	−.79±.06	−.75±.08
6. Spring plowed rotation with corn	25.4	−.64±.10	−.81±.06	+.76±.07	+.66±.10	−.86±.04	−.81±.06
7. Subsoiled	20.7	−.70±.09	−.80±.06	+.72±.08	+.51±.13	−.72±.08	−.70±.09
8. Listed	21.2	−.67±.10	−.75±.08	+.73±.08	+.72±.08	−.74±.08	−.72±.08
9. Sod breaking with alfalfa	13.7	−.59±.11	−.74±.08	+.82±.06	+.69±.09	−.84±.05	−.79±.06
10. Sod breaking with bromegrass	11.5	−.39±.15	−.56±.12	+.91±.03	+.65±.10	−.88±.04	−.83±.05
11. Disked in rotation with corn	24.2	−.62±.11	−.72±.08	+.79±.06	+.63±.10	−.84±.05	−.83±.05
12. Disked in rotation with sorgo	16.4	−.55±.12	−.71±.08	+.76±.07	+.64±.10	−.87±.04	−.83±.05
13. Disked in rotation with milo	20.7						
14. Disked in rotation with kafir	19.0	−.62±.11	−.79±.06	+.81±.06	+.67±.10	−.90±.03	−.85±.04
15. Green manured with rye	25.4	−.65±.10	−.76±.07	+.66±.10	+.66±.10	−.81±.06	−.79±.06
16. Green manured with peas	21.7	−.62±.11	−.75±.08	+.79±.06	+.66±.10	−.86±.04	−.85±.04
17. Green manured with sweet clover	20.2	−.63±.10	−.74±.08	+.63±.10	+.78±.07	−.85±.05	−.75±.08
18. Summer fallowed	31.8	−.74±.08	−.76±.07	+.74±.08	+.76±.07	−.87±.04	−.85±.04
Mean		−.62±.11	−.74±.08	+.73±.08	+.66±.10	−.82±.06	−.77±.07

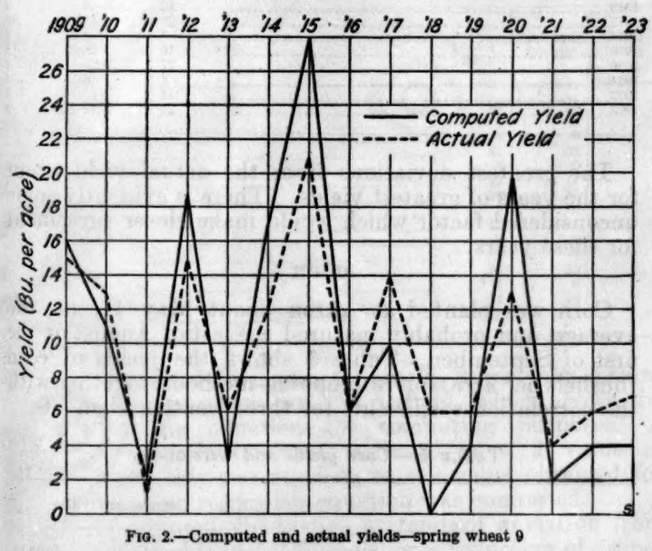


FIG. 2.—Computed and actual yields—spring wheat 9

The fallowed crop here again showed the greatest yields, while those following sod breaking showed the poorest, probably due to the fact that sod soil is mostly dry.

Smith found for oats that when the crop was forming heads cool and moderately wet weather favored the best yields. As will be seen from Table 3, the highest single factor in the growth of oats is the amount of evaporation during June and July. The correlation coefficient for these two months are much higher than any of the others. The other factors in order of importance are June evaporation and the June to August temperature. June rainfall has also a large effect on the yield. A significant thing is the high value of the evaporation correlations.

It would seem that without special cultural practices to maintain soil moisture the extremely high relative evaporation, in relation to the rainfall, would practically prevent the growth of a good crop unless some form of irrigation were carried out to supply the moisture that would normally be lost by this means.

Two multiple correlations were worked for these methods, one with oats 9 and the other with oats 10. In each case only two variables with the yield were used—the amount of June and July evaporation and the June rainfall. The values of the multiple coefficients for these were 0.88 ± 0.04 and 0.95 ± 0.02, respectively.

For oats 9 (fig. 3, *A*) the value of the June and July evaporation gave the best results. Every time the evaporation was above the normal the yield was below normal, but when the evaporation was below normal the yield was above normal only 67 per cent of the time.

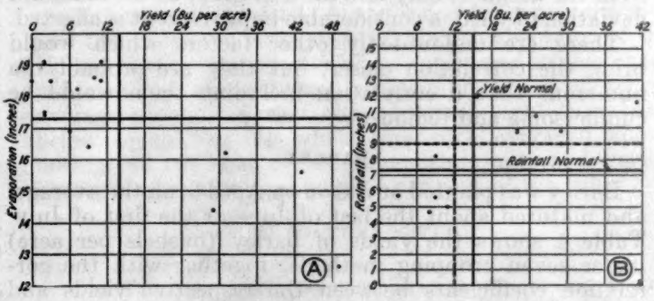

Yield (Bu. per acre)
0 6 12 18 24 30 36 42 48
Evaporation (inches)
12 13 14 15 16 17 18 19
A
Yield (Bu. per acre)
0 6 12 18 24 30 36 42
Yield Normal
Rainfall Normal
Rainfall (inches)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
B

FIG. 3, *A*.—June and July evaporation and yield of oats 9. *B*.—May to July rainfall and yield of corn 8

This would seem to indicate that there might be some other moderating factor when the evaporation was below the average, but that when above average the evaporation was practically the only cause precluding a yield above the average. The June rainfall had somewhat the same effect. When it was below the average the yield was always below, but when the rainfall was greater than the average the yield was greater only 67 per cent of the time. The combined effect of these two factors, with a coefficient of only 0.88 ± 0.04, was not considered sufficiently high to work out the regression equation for

the yields, especially in view of the comparative shortness of the record.

With oats 10, however, the effect of the evaporation was much more marked—when evaporation was above normal, yield was below normal 100 per cent of the time, and when evaporation was below the yield was above the average 83 per cent of the time. This in itself indicated the large effect that the evaporation has on crop yields at this place.

The June rainfall combined with the June–July evaporation gave a correlation coefficient of 0.95 ± 0.02, sufficiently large to justify computing the regression equation:

$$\overline{X} = 7A - 3.1B + 50.2$$

The results of computing the yield are:

Year	Computed yields	Actual yields	Difference
1909	24	20	4
1910	3	2	1
1911	0	0	0
1912	29	28	1
1913	6	2	4
1914	24	35	11
1915	38	35	3
1916	6	0	6
1917	0	3	3
1918	0	0	0
1919	7	2	5
1920	30	31	1
1921	2	4	2
1922	6	3	3
1923	13	9	4

The reduction in the standard deviation for these computations was 69 per cent. The largest difference between the computed and actual yields was that for 1914, and, with this exception, the agreements were within 6 bushels. The agreements on the large yields are, with the above exception, all very close, indicating that years with large yields were more nearly related to the weather factors than the others. The computed values agree, on the average, within 4 bushels, while the value of the standard deviation for the actual yields is 13.5 bushels. As the deviation of the computed yields from the actual is only one-third as great as the standard deviation of yield, a considerable improvement is affected.

There are undoubtedly other factors which would bring the correlation closer, but they are probably so numerous that a correlation including them would be cumbersome and tedious.

BARLEY

Barley was planted at Akron on April 6, on the average, and matured about the last of June or the first of July. Table 4 shows the yields of barley (bushels per acre) under seven cropping methods, together with the correlation coefficients between the respective yields and five weather elements.

TABLE 4.—*Barley yields and correlations*

Methods	Yields	Correlations with—				
		June mean temperature	February to June relative humidity	June rainfall	May and June rainfall	June and July evaporation
1. Fall plowed	18.0	−.53±.13	+.73±.08	+.66±.10	+.67±.10	−.67±.10
2. Spring plowed	17.1	−.58±.12	+.77±.07	+.66±.10	+.78±.07	−.76±.07
3. Spring plowed following oats	20.1	−.62±.11	+.80±.06	+.69±.09	+.83±.05	−.82±.06
4. Subsoiled	15.5	−.61±.11	+.80±.06	+.81±.06	+.71±.08	−.85±.05
5. Listed	18.6	−.69±.09	+.79±.06	+.71±.08	+.77±.07	−.81±.06
6. Disked following corn	20.8	−.60±.11	+.78±.07	+.76±.07	+.75±.08	−.85±.05
7. Summer fallowed	30.9	−.69±.09	+.81±.06	+.65±.10	+.72±.08	−.80±.06
Mean		−.62±.11	+.78±.07	+.71±.08	+.75±.08	−.80±.06

The fallowed crop gave the highest average yield, as was the case with the other grains. The yields did not vary so greatly from the average as most of the others but they were below the average about two-thirds of the time. The average yields, however, were higher in general.

The most important factor for barley at Akron is the June and July evaporation, with an average value of the correlation coefficient of -0.80 ± 0.06. The February to June relative humidity plays an important part, with a coefficient of 0.78 ± 0.07, and the May and June rainfall gave a value of 0.75 ± 0.08.

A multiple correlation with barley 3, by using (A) June and July evaporation, (B) the February to June relative humidity, and (C) the May to June rainfall, gave a coefficient of 0.92 ± 0.02 and the regression equation:

$$\overline{X} = -2.7A + 0.2B + 2.7C + 37.8$$

The computed and actual yields are given below:

Year	Computed yields	Actual yields	Difference
1909	20	22	2
1910	8	10	2
1911	0	2	2
1912	18	35	17
1913	10	8	2
1914	20	40	20
1915	39	50	11
1916	10	6	4
1917	23	33	10
1918	7	3	4
1919	10	18	8
1920	27	29	2
1921	4	8	4
1922	16	16	0
1923	24	20	4

The greatest deviations from the actual yield occur for the years of greatest yields. There is evidently some unconsidered factor which would make closer agreement for these years.

CORN

Corn was planted at Akron about May 17, on the average, and probably matured the last of August or the first of September. Table 5 shows the yields of corn (bushels per acre) for 13 cropping methods, together with the correlation coefficients for three weather elements.

TABLE 5.—*Corn yields and correlations*

Methods	Yields	Correlations with—		
		May to July rainfall	June and July evaporation	June to August mean temperature
1. Fall plowed in rotation with oats	13.6	+.74±.08	−.82±.06	−.74±.08
2. Fall plowed in rotation spring wheat	13.3	+.89±.03	−.82±.06	−.80±.06
3. Fall plowed in rotation winter wheat	12.5	+.90±.03	−.82±.06	−.77±.07
4. Fall-plowed continuous corn	17.9	+.82±.06	−.79±.06	−.68±.09
5. Spring-plowed rotation oats	13.6	+.89±.03	−.86±.04	−.73±.08
6. Spring-plowed rotation barley	15.8	+.80±.06	−.83±.05	−.72±.08
7. Spring-plowed rotation spring wheat	14.5	+.88±.04	−.81±.06	−.75±.08
8. Spring-plowed rotation winter wheat	15.5	+.89±.03	−.77±.07	−.75±.08
9. Spring-plowed continuous corn	17.6	+.71±.08	−.64±.10	−.59±.11
10. Subsoiled	16.2	+.83±.05	−.69±.09	−.64±.10
11. Fall listed	15.6	+.45±.14	−.40±.15	−.22±.17
12. Spring listed	13.9	+.54±.12	−.58±.12	−.33±.16
13. Summer fallowed	23.1	+.69±.09	−.42±.15	−.43±.14
Mean		+.77±.07	−.71±.08	−.63±.10

The results with corn are the most unsatisfactory of all the crops grown at this station. As shown in Table 5, the first seven or eight methods apparently are more affected by the weather than the last five or six.

The amount of May to July rainfall seems more important in this case than evaporation, the values of r being consistently higher than any correlations with evaporation.

If the May to July rainfall is not at least about 9 inches, or 2.3 inches above the average, the yield of corn is not above average. This is shown for corn 8 in Figure 3, *B*, where the heavy horizontal and vertical lines represent, respectively, the averages of the corn and rainfall data; the broken lines represent the apparent limits of the corn yield and rainfall. If the normals were transposed to the new positions there would be a perfect agreement between the dots and the normal lines. The corn yield would be below normal every time the rainfall was below, and vice versa. The rather close grouping of the dots indicates a close relation between this factor and the yield, although there is still some spread.

A multiple correlation computed for corn 2 and the variables, June and July evaporation, May to July rainfall, and June to August mean temperature, gave a correlation coefficient of 0.92 ± 0.02, and the regression equation:

$$\overline{X} = -2A + 2B - 2C + 173$$

The computed yields gave a standard deviation from the actual yields of 4.0, or a reduction in the standard deviation of yield of 65 per cent. The values of the computed and actual yields are given below:

Year	Computed yields	Actual yields	Difference
1909	19	22	3
1910	3	6	3
1911	0	6	6
1912	31	32	1
1913	5	0	5
1914	11	7	4
1915	33	31	2
1916	5	0	5
1917	19	13	6
1918	7	9	2
1919	5	4	1
1920	31	35	4
1921	5	6	1
1922	11	10	1
1923	21	17	4

The standard deviation, 4 bushels, is less than a third of the average yield for this method, which shows the value of the equation for computing purposes. A multiple correlation with corn 3 gave a value of 0.93 ± 0.02; this was so close to the value obtained for corn 2 that no regression equation was computed.

The computed yields give a standard deviation from the actual yields of 5.3 bushels, or a reduction of 54 per cent from the standard deviation of yields. There are some large variations, but on the whole the agreements are quite close.

It is evident from the foregoing that in regions of scanty rainfall the amount of precipitation during the critical period of growth is the determining factor in the growth of corn.

Corn 8 showed such close relation between the yield and the May to July rainfall, as shown in Figure 3, *B*, that a regression equation for these two variables was computed, as follows: $y = -16.9 + 4.3r$. The values of the computed yields from this equation were as follows:

Year	Computed yields	Actual yields	Difference
1909	25	22	3
1910	5	11	6
1911	0	0	0
1912	26	29	3
1913	7	9	2
1914	12	12	0
1915	22	29	7
1916	9	0	9
1917	26	22	4
1918	8	11	3
1919	8	3	5
1920	33	41	8
1921	3	8	5
1922	18	9	9
1923	29	25	4

SUMMARY

The general climatic features of this region make the amount of seasonal or annual precipitation the limiting factor for successful crop production. Regions of less variability of precipitation generally produce larger crops and also have smaller variations in the yields.

In regions of generally adequate summer precipitation, Ohio, for example, winter wheat averages 18 bushels to the acre, while at Akron the average is only 12.8. Spring wheat averages 15.6 bushels per acre in Ohio, but only 10.3 at Akron. Oats in Ohio average 37.8 bushels per acre; at Akron, only 22.4. Barley was 28.4 bushels in Ohio and only 20.3 at Akron. Corn shows plainly the difference in results where generally adequate moisture prevails and where it is only barely sufficient at best. In Ohio it averages 38.9 bushels; at Akron, 14.6. These averages for Ohio, it must be remembered, are for the whole State, while at Akron they are for a limited area and produced under the very best cultural methods known to science and under constant and direct supervision of highly trained agriculturists. From these few data it will be seen that the moisture, while it is evidently of major importance at Akron, is probably not the most critical factor in more humid regions.

This study indicates that growing dry-land crops under conditions such as exist at Akron is decidedly precarious—and this holds for large areas of the drier sections of the United States. Of the five crops considered in this paper winter wheat alone showed an even chance of giving an average yield; it varied above normal eight times and below seven. Spring wheat and corn averaged above normal 40 per cent of the time, while oats and barley averaged above normal only 33 per cent of the time.

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A NOTE ON MR. MITCHELL'S PAPER ON WEST INDIAN HURRICANES

By Dr. STANISLAV HANZLIK

[Bohemian Charles University, Prague]

Concerning the disturbances originating at the beginning and particularly at the end of the hurricane season over the western Caribbean Sea and Gulf of Mexico, Mr. Mitchell makes the statement that a large percentage of them reach high latitudes before dissipating. Are they not, to use Mr. Bjerknes's expression, E or F members of the cyclone family?

Mr. Mitchell, as his paper shows, collected a great amount of material that he used for charting the tracks of tropical cyclones and he could probably ascertain for each cyclonic track the approximate date of the start of the cyclonic whirl. Such data would be of value. The study of Weather Bureau charts for the United States for days previous to that date would show whether the "starter" does not enter into the Tropics from outside, from the Temperate Belt, for instance, as a strong cold wave proceeding farther south as a norther. (The statistics of cold waves in the United States are known from the late Mr. Garriott's paper.) The occurrence of northers in the locality, just before the appearance of hurricanes there would show the West Caribbean and Gulf hurricanes to be the last members of the cyclone family that is developing along the proceeding front of this polar air. These hurricanes, shifting to the higher latitudes, arrive, then, on the western European coast, say, as B or C cyclones.

Though suggesting this correlation of cold waves and northers with Caribbean and Gulf hurricanes, I will, however, not claim that the starter of each tropical cyclone must come from outside of the Tropics. It is well known that tropical cyclones are comparatively rare phenomena, certainly much rarer than the polar air entering the Tropics, as the scheme of general circulation according to Mr. Bjerknes shows.

DISCUSSION

The suggestion of Doctor Hanzlik that tropical cyclones originating in the western Caribbean and the Gulf of Mexico may be the last members, E or F, of a cyclone family that is developing along the polar front, is doubtless a natural one to make by one familiar with the development and movement of cyclones in groups or families as in Europe. In North America, as pointed out by Henry (MO. WEA. REV., 50: 473), cyclones do not develop and move in families, and moreover, in the months of June to September there is little or no evidence of the movement of surface air from polar regions; in other words, polar air in those months is practically nonexistent so far as the Gulf of Mexico and the Caribbean are concerned. For this reason, and on account of the rarity of cyclonic development in this region in July and August, the cyclones of these two months are not considered in the tabulation which will be presented below.

The sweep of polar air southward over the Gulf of Mexico does not begin until late October and is not pronounced until still later in the cold season. However, I have made an examination of the daily weather charts for the three days preceding and the three days following the origin of West Indian hurricanes. The criterion adopted to show the arrival of polar air in these regions was the advance of an area of high pressure and cooler air southward over the Plains States and Texas, accompanied by a norther over the western Gulf of Mexico. Experience has shown that fresh northerly winds on the Texas coast with a pressure distribution of that character means strong northerly winds farther south, especially in the Tampico and Vera Cruz regions of Mexico.

Relation of tropical cyclones to northers in the western Caribbean Sea and Gulf of Mexico

Cyclones preceded by northers over western Gulf of Mexico one to three days previous to development of cyclonic whirl:

Oct. 8, 1888 (1 day before).	Oct. 9, 1906 (3 days before).
Oct. 6, 1891 (1 day before).	Oct. 25, 1908 (2 days before).
Oct. 2, 1895 (1 day before).	Oct. 2, 1912 (2 days before).
Oct. 13, 1895 (1 day before).	Oct. 22, 1923 (2 days before).
Oct. 9, 1900 (1 day before).	Nov. 11, 1916 (2 days before).
Oct. 7, 1902 (3 days before).	Total, 11.

Cyclones followed by northers same day to two days after development:

Oct. 9, 1887 (2 days later.)	Oct. 27, 1913 (same day).
Oct. 5, 1889 (1 day later).	Oct. 10, 1916 (same day).
Oct. 21, 1892 (2 days later).	Nov. 5, 1893 (same day).
Oct. 7, 1896 (same day).	Nov. 11, 1904 (same day).
Oct. 11, 1912 (1 day later).	Total, 9.

Cyclones neither preceded nor followed by northers (within two or three days):

June 10, 1889.	Sept. 28, 1895.	Oct. 3, 1905.
June 15, 1889.	Sept. 11, 1912.	Oct. 17, 1908.
June 12, 1895.	Sept. 1, 1915.	Oct. 6, 1909.
June 10, 1901.	Sept. 19, 1920.	Oct. 11, 1910.
June 11, 1902.	Sept. 27, 1920.	Oct. 24, 1914.
June 19, 1902.	Sept. 6, 1921.	Oct. 21, 1921.
June 7, 1906.	Oct. 7, 1886.	Oct. 12, 1922.
June 12, 1906.	Oct. 29, 1887.	Oct. 14, 1922.
June 25, 1909.	Oct. 20, 1893.	Oct. 13, 1923.
June 26, 1909.	Oct. 1, 1894.	Nov. 6, 1906.
June 7, 1912.	Oct. 2, 1899.	Nov. 8, 1909.
June 22, 1913.	Oct. 26, 1899.	Nov. 22, 1909.
June 15, 1921.	Oct. 10, 1904.	Nov. 11, 1912.
June 13, 1922.	Oct. 29, 1904.	Total, 41.

Inasmuch as none of the June or September cyclones was either preceded or followed by a norther over the western Gulf of Mexico, the advent of polar air in the Tropics can not be regarded as even a contributing cause of the storms of those months. Moreover, only 10 of the 34 October and 1 of the 7 November cyclones were preceded by northers, so that the advent of polar air could have been a factor in the development of only 11 of the 61 tropical cyclones considered.

On pages 16–17 of SUPPLEMENT NO. 24, MONTHLY WEATHER REVIEW, is a discussion of the two principal regions where tropical cyclones develop in the North Atlantic Ocean. On page 17 it is stated:

> Over the western third of the Caribbean Sea, especially in the region a short distance north of the Isthmus of Panama, a belt of doldrums appears at times, especially at the beginning and near the end of the hurricane season. This, quite likely, is the extreme eastern end of the Pacific belt of doldrums, which is usually just south of the Isthmus of Panama, * * * and which has shifted northward beyond latitude 10° N. Thus conditions in the western Caribbean Sea at these times become as favorable for the development of a cyclonic disturbance as they are in the region south of the Cape Verde Islands in the months of August and September.

The favorable conditions referred to are high temperature, high humidity, and a doldrum condition of light, variable winds, and these conditions must exist far enough north of the Equator so that in addition to the northeast trades north of the doldrums there shall be south of them the southeast trades which have crossed the Equator and become southwest winds due to the deflective effect of the earth's rotation. These, to me, seem the ideal conditions for the development of unstable, squally weather and the initiation of a cyclonic whirl in the lower atmosphere.—*C. L. Mitchell.*

COMPENSATION OF ALTIMETERS AND ALTIGRAPHS FOR AIR TEMPERATURE

By W. G. BROMBACHER

[Bureau of Standards, Washington, D. C.]

(Abstract of paper presented to American Meteorological Society, Washington, D. C., May 1, 1926)

The altitudes of aircraft are usually determined by an altimeter, which is an aneroid barometer calibrated to an altitude-pressure relation containing an arbitrary altitude-temperature assumption. If the correction due to the variation of the temperature from that of the altitude-temperature assumption is required, additional observations are needed, namely, free-air temperatures from the ground level to the altitude. For the accuracy required in aeronautics, altitudes should be determined by both pressure and temperature measurements. It is difficult to take account of the mean temperature term of the barometric formula mechanically in an instrument. The following new relation based on the summer, winter, and yearly averages of observations of upper-air temperatures at latitude 40° in the United States is presented as a substitute. Up to 30,000 feet it is found that for a given altitude free-air pressures plotted against free-air temperatures give straight lines. This relation is based on standard sea-level pressure. Mathematically,

$$\frac{dP}{dT}=A_h \qquad (1)$$

where P is the pressure and T the absolute temperature at the altitude h, and A_h is a constant for any one altitude. In order to have a simple compensating mechanism, the amount of compensation in pressure units per degree change in air temperature per unit change in air pressure should be constant. This desirable relation may be stated in symbols,

$$\frac{dP}{(P_o-P)\,dT}=\frac{A_h}{P_o-P}=K \qquad (2)$$

where $P_o=760$ millimeters of mercury and K is a constant.

The values found for A_h and K are given below.

Altitude	A_h Mm. Hg. per °C.	K Compensation in mm. Hg. per °C. per mm. Hg. change in pressure
Feet		
4,000	0.375	0.0036
8,000	.750	.0038
12,000	1.04	.0038
16,000	1.15	.0033
20,000	1.20	.0029
24,000	1.20	.0026
30,000	1.20	.0023

It will be seen that the value of K varies with altitude. The adoption of a value of 0.0029 for K gives rise to maximum deviations varying from 0 to 3.5 per cent of the altitude, while the compensation given by this value of K under the same conditions amounts to about 9 per cent.

In order to test this method of compensation further the values were compared with values of free air pressure determined by 15 observed altitude-temperatures curves which contained marked "temperature inversions." These curves were obtained from the aerological division of the United States Weather Bureau. The compensation given in the table compared with that required for these abnormal distributions of temperature was complete on the average within 10 to 20 per cent.

The multiplication of the mechanism of an altimeter or altigraph may be modified by the insertion of a temperature element or manually operated device so as to compensate according to the values of K given in the table, or more simply, to the average value of K. An instrument so compensated is said to be compensated for air temperature. If a manually operated device modifies the multiplication according to average values of K corresponding to free-air temperature and if the temperature dial is graduated in terms of ground level temperatures, the instrument is said to be compensated for ground temperature. The essential difference in the two types of compensation lies in the fact that in the first the compensation depends on free-air temperature, while in the second on air temperature at the ground level.

The Bureau of Standards has under construction an altigraph compensated for air temperature and an altimeter compensated for ground temperature.

NOTES, ABSTRACTS, AND REVIEWS

TRANSMISSION OF METEOROLOGICAL CHARTS BY RADIO IN EUROPE

The broadcasting station at Munich will henceforth transmit meteorological charts by radio every week-day morning about 9 a. m. and on Sundays and holidays at 12.15, using the Dieckmann telephotographic system.

According to the Manchester Guardian, the Munich distributing station receives for this purpose from the Central Meteorological Office of Bavaria a chart made with a special nonconducting ink and traced complete on a conducting sheet of metal.

The chart is rolled upon a drum turned by a clockwork mechanism, and on this drum rests a very fine transmitting stylus, which is moved along parallel with the axis of the drum. Thus the stylus describes upon the chart a spiral of very closely spaced lines.

According as the stylus is in contact with a conducting or a nonconducting part, a circuit is opened or closed and the currents are sent by wire to the Munich station, which in turn transmits them by radio. At the receiving stations a special chemical paper is used. Each transmission lasts about five minutes.—*La Nature, July 17, 1926. Translation B. M. V.*

THE FUTURE OF AEROLOGY

By W. PEPPLER

[Abstract by H. C. Frankenfield from "Das Wetter," Heft 3, March, 1926]

(1) Aerology during the last 10 years has virtually been at a standstill.

(2) Aerological accomplishments of the last 20 years made possible the development of the Bjerknes theories, and their further progress depends entirely upon aerology.

(3) Especially necessary for the future of aerology is an intensive investigation of the upper half of the troposphere and the lower portion of the stratosphere. Little is known of the alto-cumulus and the cirrus. Knowledge of the strata above 4 k. m. is more important than that of the lower strata.

(4) The first step should be a complete reorganization of observational methods. Earlier observations are only partially comparable.

(5) A more accurate survey of the aerological conditions of the air strata up to about 1,000 meters is also necessary. In the present method of conducting captive-balloon ascents detailed registration is lost for the most part. A knowledge of the turbulence as well as of the structure of the strata near the surface can also be acquired.

(6) Special results are expected from the systematic coordination of radiation measurements with aerology. Radiation apparatus has not yet been successfully devised that will permit aerological technique to be placed in direct service for radiation investigation.

(7) Investigation of the influence of turbidity particles by the customary methods is already possible through the Wigand visibility measure.

(8) Measurements of incoming and outgoing radiation should be made.

(9) The airplane offers a new and very important factor for the future of aerology, as, on account of its mobility, it is superior in many respects to the old methods, especially for the study of optics, atmospheric electricity, turbulence, radiation, clouds, etc. An efficient airplane meteorograph has been devised.

(10) Old and new methods should be combined and considered together.

(11) We are still far removed from the ideal observatory, and only a small portion of the apparent problems can now be attacked. Present observatories are not well located, and they are too much occupied with practical problems. We have aerological observatories *but no research aerological institutes*. Research must form the fundamental basis, and it must not be strangled by the practical work. The idea that scientific progress is developed from practical work is incorrect. The path of meteorology and weather forecasting leads only over free scientific research.

A LIGHTNING STROKE FAR FROM THE THUNDER-STORM CLOUD

Mr. J. H. Armington sends us from Indianapolis the report printed below, which was sent to him by Prof. Z. A. McCaughan, of Bloomington, Ind. The stroke occurred about 1 p. m. on July 23, 1926, in Monroe County; it it killed two children.

I drove to the place referred to and made personal inquiry of people who were within 100 yards of the place. The sun was shining, the nearest cloud seemed to the witnesses 2½ or 3 miles north (toward Clear Creek and Bloomington). They had heard no thunder previous to this stroke and heard only two or three of distant thunder afterward. Their sky stayed clear for two hours afterwards. At the time of this stroke we were having frequent strokes of lightning and thunder here at Bloomington and we had 0.23 inch of rain. Three miles southeast of Bloomington there was a small tornado that broke limbs of trees and carried away anything small that was loose. The lightning was severe. Witnesses near where the children were killed say the lightning traveled horizontally from north to south. It passed three buildings, missing them by about 100 feet, and struck this little house just above the top of the corner foundation post.

The striking of lightning, through clear sky, at points somewhat distant from the region immediately beneath the storm cloud, while relatively rare, occurs probably more frequently than is realized.

During a three-year residence in east-central Florida I observed the phenomenon at least three times. The typical local thunderstorm cloud of the Florida summer grows with great rapidity, and is usually an entity quite unconnected with storms of the same kind that may be developing elsewhere within the observer's field of view. Opportunities for watching the lightning strokes from individual clouds are therefore excellent.

It is my recollection that the distance along the ground between a vertical dropped from the edge of the cloud and the striking point of the bolt was of the order of the height of the cloud base above ground. How foreshortening affected this estimate is of course impossible to say. But it is probably true that the distances were never of the order of 2 to 3 miles, as in the extraordinary case described by Professor McCaughan. In one instance (and I think this was true of all these far flung bolts) the spark seemed to leave the cloud from a point at least halfway up from cloud base to summit, and in this one instance which I recall especially vividly it was about three quarters of the way.—*B. M. V.*

LITERATURE ON THE NORMAL DENSITIES OF GASES

Scientific Paper of the Bureau of Standards, No. 529, bears the title "A Review of the Literature Relating to the Normal Densities of Gases," and was prepared by M. S. Blanchard and S. F. Pickering. The authors state in their abstract that—

* * * the attempt is made to choose the most reliable value for each gas. The number of sources of the gas in question, the methods used for its purification, the precautions observed in making the experimental measurements, the number of observations made, the agreement between observations of a set and the concordance between the results of the different observers have all been carefully considered in the selection of the final value. While many of the early determinations of historical interest have been included in general, only those which should be considered in selecting the final value have been critically reviewed.

THE SUMMER OF 1926 IN THE UNITED STATES

Summer is usually considered to cover the three months from June to August, inclusive. The records for these months of 1926 show about the usual run of variations in weather, with alternately warm and cool and rainy and dry in different sections and during different times in the season. For the summer, as a whole, the temperature was remarkably uniform, and was slightly above normal over much the greater portion of the country. The seasonal average was 1° to 3° below normal in most sections from the Ohio Valley and Middle Atlantic States northward, and 1° below at about half the stations in the Gulf area. In all other sections the temperature averaged from normal to as much as 6° above, the greatest plus departures being in the more western States.

Rainfall was deficient in most of the Northeast, the south Atlantic area, in nearly all of the Great Plains and North Central States, and also in most places in the far Southwest. Elsewhere the amounts were above normal.

For the country, as a whole, about 40 per cent of the stations had more than normal rainfall and the others less than normal.—*Reprint from Weather and Crop Bulletin, September 7.*

FIFTH SUCCESSIVE FAVORABLE MONSOON PROBABLE IN INDIA

For the fifth successive year reports from India indicate that the monsoon, or rainy season, will be favorable. A cable received on August 23 from Trade Commissioner C. B. Spofford, Calcutta, states that to date rainfall was slightly above normal on the northwest frontier, and in Rajputana, central India, the Central Provinces, Hyderabad, and Madras; and normal throughout all other regions. It is still blowing actively and the Indian Government forecast for August and September indicates normal rainfall in northwest India and normal or excess on the peninsula.—*Reprint from Commerce Reports, September 6, 1926, No. 36.*

METEOROLOGICAL SUMMARY FOR SOUTHERN SOUTH AMERICA, JULY, 1926

By Señor J. B. NAVARRETE, DIRECTOR

[El Salto Observatory, Santiago, Chile]

The first half of July was much the more rainy, in contrast to the second half, which was relatively dry.

The month opened with an important anticyclonic center off the central zone, with a maximum pressure of 768 mm. at the Island of Juan Fernandez.

Between the 3d and the 6th a large depression crossed the far southern region and showed its influence throughout the country in general bad weather, heavy winds and rains. The maximum precipitation in a day was observed on the 6th at San Fernando, 81 mm. Increases in river stages and floods were general.

From the 7th to the 9th the bad weather abated temporarily, while the pressure rose and continued variable, with low temperatures.

Between the 10th and 13th another great depression affected the country, causing general bad weather, violent winds, and rains as far as Coquimbo, where on the 11th there was observed a 24-hour rainfall of 44 mm. Heavy as this was, the maximum rainfall occurred on the 13th at San Fernando, 79 mm. in 24 hours. Again there was a general rise of rivers and occurrence of floods.

On the 14th and 15th the bad weather moderated, upon the establishment of anticyclonic control over the country. On the 16th and 17th there were scattered and light rains as far north as Valdivia.

Between the 19th and 21st a fairly important depression influenced the country; the change of weather began with heavy mists in the central zone, and ended on the 21st with a rain from Valparaiso to Valdivia. Maximum precipitation was registered at Arauco, 23 mm. in 24 hours. The weather then continued variable; fine weather occurred again on the 22d; on the 23d a new depression crossed the southern zone, and on the early morning of the 24th there were violent squalls of rain and snow in the central zone as far north as Santiago. On the 25th general fine weather was reestablished, anticyclonic control dominating the whole country.

Between the 26th and 28th a depression crossed the far south, causing dense mists and light rains in the southern zone, which extended into the central zone as far as Santiago.

On the 29th and 30th the weather was again fine, but on the 31st a large depression began to influence the southern part of the country, breaking with a violent storm of wind and rain between Arauco and Chiloe.

To summarize, the month of July showed a much more boisterous first half, a second half of more stable character; but in the last days of the month a new period of foul weather was threatening in the south.—*Transl. B. M. V.*

METEOROLOGICAL SUMMARY FOR BRAZIL, JULY, 1926

By FRANCISCO SOUZA, Acting Director

[Directoria de Meteorologia, Rio de Janeiro]

During July the circulation in the lower strata of the atmosphere was rather active; six anticyclones entered the southern part of the continent, most of them very extensive; the continental depression and those of high latitudes showed unusual activity during the period. Practically all the paths of the anticyclones were normal. Frosts continued to be observed in the southern part of the country.

Rainfall was in general scant, except in parts of the central and southern region, where the values averaged above normal.

The blooming and growth of cane and tobacco were hindered by frosts and lack of rain. In the State of Bahia and in the northern part of the country atmospheric conditions were favorable to cacao and cotton. Wheat made good growth. The harvests of cotton and coffee in the central and southern part of the country are not giving good yields, and those of cane in the northern part are not promising.

Weather conditions in Rio de Janeiro were in general good, with much cloudiness. In temperature the days were relatively warm, and they were dry; but the nights were fresh and sometimes cold. Rainfall during the month was pitifully small. During a period of 75 years, or since 1851, there have been seven years in which the month of July showed rainfall similar to or at times lower than this.—*Transl. W. W. R. and B. M. V.*

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING AUGUST, 1926

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1924, **52** : 42, January, 1925, **53** : 29, and July, 1925, **53** : 318.

From Table 1 it is seen that solar radiation intensities averaged slightly below the normal for August at Madison, Wis., and close to normal at Washington, D. C., and Lincoln, Nebr.

Table 2 shows a pronounced deficiency in the amount of radiation received on a horizontal surface from the sun and sky at Washington and Madison and a slight excess at Lincoln.

Skylight-polarization measurements made on four days at Washington give a mean of 54 per cent, with a maximum of 58 per cent on the 26th. Measurements made on six days at Madison give a mean of 55 per cent, with a maximum of 64 per cent on the 14th. These are below the corresponding average values for August at both stations.

TABLE 1.—*Solar radiation intensities during August, 1926*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Aug. 3	20. 57	0. 53	0. 65	0. 76	0. 95	1. 19					18. 59
9	11. 38				1. 03	1. 21					12. 68
26	12. 68					1. 41	1. 06	0. 74	0. 61		9. 47
27	13. 61				0. 76						15. 11
28	14. 60				0. 88	1. 23	0. 98				10. 21
30	15. 11						0. 98				10. 21
31	10. 97		0. 69	0. 86	1. 02	1. 28					9. 47
Means		(0. 53)	(0. 67)	(0. 81)	0. 93	1. 26	1. 01	(0. 74)	(0. 61)		
Departures		−0. 13	−0. 01	+0. 04	±0. 00	+0. 04	±0. 00	−0. 13	−0. 12		

*Extrapolated.

TABLE 1.—*Solar radiation intensities during August, 1926*—Con.

MADISON, WIS.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal*	*mm.*
Aug. 6	14. 60					1. 11					10. 59
14	12. 24					1. 20					13. 13
21	12. 24			0. 94	1. 05	1. 37					13. 13
24	10. 97			0. 82							11. 38
25	10. 59			1. 00							10. 97
27	13. 61			0. 79	1. 00						13. 61
28	14. 10			0. 88	1. 05						15. 11
30	8. 48			0. 96	1. 13						8. 48
31	9. 47				0. 96						9. 47
Means				0. 90	1. 04	1. 23					
Departures				−0. 04	−0. 06	−0. 08					

LINCOLN, NEBR.

Aug. 2	12. 68						0. 89	0. 76	0. 65		13. 13
7	10. 59		0. 48	0. 66	0. 90						9. 14
9	15. 11					1. 25	1. 01	0. 74	0. 58	0. 49	15. 11
17	15. 11					1. 27	0. 96	0. 72			15. 65
20	13. 61	0. 76	0. 79	0. 97	1. 16	1. 33	1. 16	0. 99	0. 90	0. 76	14. 10
23	14. 60						1. 18	0. 97	0. 87	0. 71	12. 24
24	10. 97		0. 79	0. 90	1. 13	1. 39	1. 09	0. 87	0. 65	0. 63	8. 48
25	10. 21		0. 86	1. 01	1. 19	1. 39					11. 38
26	12. 24					1. 30	1. 05	0. 87	0. 72	0. 59	8. 18
27	11. 38		0. 95	1. 07	1. 21	1. 41	1. 17	0. 97	0. 84	0. 72	9. 47
28	15. 11		0. 89	0. 99	1. 08	1. 30					12. 68
Means		(0. 76)	0. 79	0. 93	1. 11	1. 33	1. 06	0. 86	0. 74	0. 65	
Departures		+0. 11	+0. 02	+0. 03	+0. 03	+0. 04	−0. 01	−0. 03	−0. 01	−0. 04	

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning—	Average daily radiation: Washington	Madison	Lincoln	Chicago	New York	Average daily departure from normal: Washington	Madison	Lincoln
1926	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
July 30	391	300	565	242	313	−68	−170	+31
Aug. 6	446	365	500	323	340	−4	−90	−16
13	228	459	490	298	241	−207	+18	−4
20	195	418	554	329	191	−224	−7	+72
27	491	437	416	311	344	+86	+34	−46
Excess or deficiency since first of year on Sept. 2						−2, 072	+1, 883	+637

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS

NORTH ATLANTIC OCEAN

By F. G. TINGLEY

There was a noticeable increase in atmospheric activity over the North Atlantic in August as compared to July. Whereas in July the number of gales reported was smaller than normal for that month the number in August was markedly larger. While some of them were occasioned by the two disturbances of tropical origin, a considerable number was due to developments in the higher latitudes. The depression of the 16th to 19th in the northeastern Atlantic gave rise to widespread gales, the weather maps resembling those of the mid-winter season as regards the number and distribution of gales reported. The strength of the gales was less, however, ranging generally from force 7 to 9.

The general distribution of pressure throughout the North Atlantic for August is shown in an accompanying table. The departures from normal are moderate in amount and give no indication of the activity in air movement reported by vessels.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level 8 a. m. (75th meridian time), North Atlantic Ocean, August, 1926*

Station	Average pressure	Departure [1]	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	[2] 29.65	([3])	30.00	10th	29.30	6th.
St. Johns, Newfoundland	29.90	−0.09	30.22	23d	29.56	21st.
Nantucket	30.01	+0.01	30.36	21st [4]	29.76	8th.
Hatteras	30.02	−0.02	30.16	11th [4]	29.88	6th.
Key West	30.02	+0.04	30.08	31st	29.94	Do.
Swan Island	29.87	−0.04	29.92	8th [4]	29.80	21st.
New Orleans	30.00	+0.03	30.12	4th [4]	29.60	26th.
Turks Island	30.06	+0.06	30.14	18th [4]	29.96	5th.
Bermuda	30.14	+0.05	30.30	14th	29.66	6th.
Horta, Azores [5]	30.21	+0.01	30.44	6th	29.96	26th.
Lerwick, Shetland Islands	29.85	+0.05	30.33	3d	28.93	21st.
Valencia, Ireland	30.05	+0.13	30.43	2d	29.60	20th.
London	30.08	+0.10	30.38	27th	29.75	21st.

[1] From normals shown on H. O. Pilot Chart, based on observations at Greenwich mean noon, or 7 a. m., 75th meridian.
[2] Mean of 27 days.
[3] New station; no normal established.
[4] And on other dates.
[5] Observations made at 7 a. m.

The amount and distribution of fog conformed closely to the normal for August.

The month opened with generally quiet conditions over the northern part of the ocean, though vessels northwest of Ireland reported moderate to fresh gales, occasioned by a depression then approaching Iceland. In southern waters, however, a tropical disturbance was moving westward in mid-ocean. On the 1st the Dutch steamship *Bellatrix*, bound from Norfolk to Buenos Aires, and at Greenwich mean noon of that day, in 23° 34′ N., 59° 01′ W., came within the influence of this disturbance. In the course of the day storm winds were experienced, the center passing north and east of the vessel at 3:50 p. m. with the barometer recording 29.39 inches. The report from the *Bellatrix* is the earliest to show the existence of the disturbance. This hurricane passed near Bermuda on the 6th and was in the vicinity of Newfoundland on the 8th. It is reported to have caused a number of casualties in the fishing fleets on the Grand Banks on the 7th and 8th. It is impossible to trace the further course of the storm with certainty, but it appears to have ultimately reached the eastern part of the ocean, though possibly in combination with some extratropical depression.

As the path of this hurricane crossed the trans-Atlantic steamer lanes a large number of vessels came under its influence. The masters of some of these vessels, appreciating the situation, exchanged weather reports by radio, using the information thus obtained to avoid the storm center. An indication of the amount of data available under such circumstances is afforded by a chart reaching the Weather Bureau from Capt. H. E. Maber, master of the British steamship *Emlynian*. On the 7th Captain Maber obtained reports from no less than 14 vessels within the area between 39° and 43° N., 59° and 66° W. From these reports he was able to plot the path of the approaching storm with a good degree of accuracy.

A detailed account of this hurricane appears elsewhere in the REVIEW.

As it pursued its course eastward across the ocean it was closely followed by a depression that developed near Newfoundland on the 12th. This latter, upon reaching the eastern North Atlantic developed into a vigorous storm, causing gales over an extensive area and involving many vessels, especially on the 17th to 19th. Representative reports on this storm will be found in the accompanying table of gales. In turn, this storm left a fresh depression forming in its wake, central on the 21st in 43° N., 40° W. The latter moved northeastward, reaching Iceland on the morning of the 24th, with readings at the center as low as 28.94 inches.

The daily weather maps of August disclose an interesting and rather unusual movement of an anticyclone during the last half of the month. On the 16th a small HIGH appeared over the Dakotas, moving thence eastward with gradually increasing intensity until on the 20th and 21st it covered New England and the Canadian maritime Provinces. The central pressure on the 21st was 30.44 inches. Its subsequent course can be plainly traced across the Atlantic. On the 26th it was approaching the British Isles and on the 30th it largely dominated the weather of western and central Europe. On the 31st, as shown by the British map of that date, the center was over Russia, with a central isobar of 1,028 millibars (30.36 inches).

On the 22d a depression formed in the western Caribbean Sea and moved northwestward through the Yucatan Channel into the Gulf of Mexico. It developed into a hurricane, an account of which appears elsewhere in the REVIEW.

On the 27th a moderate depression formed east of Newfoundland, whence it moved slowly eastward, giving rise to moderate and fresh gales over the northern steamer routes. On the 29th, in conjunction with a depression from off the west coast of Spain, it formed a double-centered depression extending from Iceland to the region southwest of Ireland.

OCEAN GALES AND STORMS, AUGUST, 1926

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Pres. Harding, Am. S. S.	New York	Cobh	45 15N.	37 16W.	July 31	8p, 1st	3d	29.76	ENE.	S., 7	S.	S., 8	ENE-E-S.
Balsam, Am. S. S.	Belfast	New York	55 22N.	17 56W.	31	5a, 1st	1st	29.77	SSE.	SSW., 10	WSW.	SSW., 10	SSW-SW.
Nesian, Br. S. S.	Antwerp	Boston	45 23N.	36 25W.	Aug. 1	8a, 2d	2d	29.79	S.	W., 8	W.	WNW., 8	S-W-WNW.
Bellatrix, Du. S. S.	Norfolk	Buenos Aires	22 16N.	56 02W.	1	3.50p, 1st	2d	29.39	NE.	N., 10	SW.	NxW., 11	NNE-N.
Saguache, Am. S. S.	Hamburg	Galveston	29 30N.	61 54W.	3	7.52a, 3d	4th	29.77	E.	E.	NE.	E., 9	E-NE.
Wellfield, Br. S. S.	Lands End	Key West	29 44N.	67 10W.	4	4a, 5th	5th	29.75	E.	NE., 9	NW.	NE., 9	NE-N.
Colorado Springs, Am. S. S.	Manchester	New Orleans	31 28N.	66 56W.	5	3a, 6th	6th	28.87	SE.	NE., 12	NW.	NE., 12	E-NE-N.
San Gerardo, Br. S. S.	London	Tuxpam	[1] 30 21N.	[1] 65 03W.	5	5.30p, 5th	6th	29.08	ESE.	NE., 12	W.	NNE., 12	NE-NNE.
Caracas, Am. S. S.	New York	Curacao	31 52N.	69 58W.	6	Noon, 6th	7th	29.78	NE.	NW., 8	W.	NW., 8	NE-NW-W.
Roma, Fr. S. S.	Marseille	New York	38 10N.	63 44W.	6	a, 7th	7th	29.32	W.	S., 10	WSW.	S., 10	W-S-WSW.
Orca, Br. S. S.	Cherbourg	do	40 50N.	62 10W.	7	6p, 7th	8th	28.80	SSE.	SW., 10-12	W.	SW., 12	S-W-N-SW.
Minnewaska, Br. S. S.	London	do	41 30N.	60 45W.	7	11.30p, 7th	8th	29.40	SE.	SxW., 9	WSW.	SW., 11	S-SSW.
Balsam, Am. S. S.	Belfast	do	44 27N.	57 29W.	8	10a, 8th	8th	29.67	SSE.	SSE., 9	SW.	SW., 10	SSE-SW.
Esparto, Am. S. S.	New York	Cristobal	38 35N.	73 51W.	14	9.15p, 14th	14th	29.97	W.	W., 10	NW.	W., 10	W-NW.
Brave Coeur, Am. S. S.	Rotterdam	Galveston	46 31N.	16 43W.	15	3.30p, 15th	17th	29.34	S.	S., 8	W.	S., 8	S-W.
Winifredian, Br. S. S.	Liverpool	Boston	46 34N.	34 44W.	16	Noon, 16th	17th	29.32	SExS.	WSW., 6-7	WNW.	WxN., 9	SxE-WSW.
Baron Nairn, Br. S. S.	Antwerp	Norfolk	48 30N.	36 34W.	16	4.30p, 16th	17th	29.06	SW.	NNW., 10	NW.	NNW., 10	NNW-N.
New York City, Br. S. S.	Bristol	Philadelphia	50 46N.	21 13W.	16	11a. 17th	19th	28.77	SW.	SW., 9	NW.	SW., 9	SW-WSW.
United States, Dan. S. S.	New York	Christiansand	54 55N.	25 27W.	16	4a, 19th	19th	29.10	WNW.	WSW., 7	SW.	WNW., 9	WNW-SW.
Saramacca, Am. S. S.	New Orleans	Belize	23 44N.	88 04W.	22	12a, 23d	23rd	29.34	NE.	NE., 8	S.	NE., 8	NE-S.
Olancho, Hon. S. S.	do	Puerto Cortez	23 50N.	87 50W.	22	1a, 23d	23d	29.58	NE.	SE., 10	SSE.	SE., 10	ESE-SSE.
Morazan, Hon. S. S.	Vera Cruz	New Orleans	27 36N.	89 44W.	23	Noon, 25th	26th	29.62	S.	SSW.	SW.	SSW., 9	S-SSW.
Crudoil	New Orleans	Miami	29 50N.	89 50W.	25	10p, 25th	26th	29.40	SE.	SE., 10	S.	—10-11	SE-SSE.
W. C. Teagle	New York	Baton Rouge	28 59N.	89 07W.	26	1.30a, 26th	27th	29.49	SE.	SE., 8	NW.	—11	SW-NW.
NORTH PACIFIC OCEAN													
Oakridge, Am. S. S.	Portland	Yokohama	45 57N.	154 59E.	4th	10a, 5th	5th	29.56	SSW.	S., 5	S.	SSE., 8	None.
Dilworth, Am. S. S.	Manila	San Francisco	46 16N.	149 52W.	9th	2a, 10th	10th	29.79	SE.	SE., 7	SE.	SE., 8	Steady.
Victorious, Am. S. S.	Panama	Honolulu	*18 N.	*125 W.	11th	2p, 15th	15th	29.44	E.	SW., 9	S.	—10	Variable.
West Carmona, Am. S. S.	Manila	San Francisco.	37 52N.	149 50E.	17th	4p, 18th	19th	29.38	SSE.	ESE., 9	NE.	ESE., 11	SE-ESE.
Akagisan Maru, Jap. S. S.	Yokohama	do	43 55N.	162 E.	17th	5 p, 20th	21st	28.95	SW.	W., 8		NW., 10	NNW-W.
West Henshaw, Am. S. S.	Slain, P. I.	do	17 35N.	128 25E.	21st	4p	21st	29.60		WSW., 8	SW.	WSW., 8	W-S.
Tenyo Maru, Jap. S. S.	Yokohama	Honolulu	34 42N.	153 33E.	22d	4p, 22d	23d	29.83	E.	E., 8	ESE.	E., 8	E-ESE.
Volunteer, Am. S. S.	Honolulu	Panama	18 38N.	125 36W.	22d	11p, 22d	23d	29.60	NNE.	E., 9	SSE.	E., 9	NE-E.
Somedono Maru, Jap. S. S.	Wakamatsu	Portland	51 46N.	166 25W.	28th	9p, 28th	30th	29.21	NW.	NW., 4	W.	NW., 9	4 points.
Tatsuno Maru, Jap. S. S.	Yokohama	San Francisco.	44 38N.	169 25W.	29th	Noon, 30th	31st	29.26	SSE.	SSE., 9	SW.	SSE., 9	2 points.
Shabonee, Br. S. S.	Shanghai	San Pedro	49 37N.	167 29W.	30th	3p, 30th	31st	29.22	E.	E., 6	NE.	E., 9	E-ENE.
Salina, Am. S. S.	Manila	San Francisco.	47 30N.	179 30E.	30th	8a, 31st	Sept. 1	29.17	SE.	NE., 10	NW.	NE., 10	SE-E-NE-N-NW.
SOUTH PACIFIC OCEAN													
Tahiti, Br. S. S.	San Francisco.	Sydney, N. S. W.	28 35S.	164 24E.	5th	8a	Aug. 5 5th	29.19	NW.	WNW., 9	SSW.	WNW., 9	WNW-SSW.

[1] Noon position, steering S. 67 W.

* Approximate position.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

The most important weather change since July over the northern part of the ocean was the considerable lessening in the occurrence of fog. July was essentially a foggy month above the 40th parallel, a general condition which continued through the first decade of August. Thereafter only scattered fog was observed until the 27th, after which until the 31st it was prevalent over the area bounded roughly by 140° and 170° west longitude, 40° and 50° north latitude. Locally, fog occurred frequently off a considerable length of the coast near San Francisco.

Little cyclonic activity occurred in the Aleutian region until the 13th, but after the 15th a LOW overlay Alaska and the adjacent waters. There were few gales in this region, however, and these were confined mostly to the last three days of the month, when winds of force 9 to 10 roughened the central part of the upper steamer routes.

On the 8th a small LOW formed near 45° N., 155° W. It continued shallow throughout its northward movement and caused no gales, except on the 10th, when a maximum force of 8, SE., was experienced near 46° N., 150° W.

The North Pacific HIGH dominated the weather for the most part over the great central region east of the 180th meridian. It was disturbed on its eastern boundary on the 21st to 24th, when a shallow low pressure area formed and lay at some distance off the northern coast of the United States, moved slightly northward, and died out without causing winds of consequence.

Pressure conditions over the eastern half of the ocean were of a mild type, with only slight departures from the normal, as shown by the following table:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean, August, 1926*

Station	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Dutch Harbor [1 4]	29.80	−0.10	30.16	26th	29.12	28th.
St. Paul [1 4]	29.85	+0.09	30.16	do	29.24	22d.
Kodiak [1]	29.87	+0.02	30.24	6th	29.16	29th.
Midway Island [1 5]	30.09	0.00	30.18	4th	30.00	24th.[6]
Honolulu [2]	30.01	0.00	30.09	29th	29.90	10th.
Juneau [2]	29.96	−0.06	30.30	8th	29.40	18th.
Tatoosh Island [2 3]	30.02	−0.03	30.25	1st	29.69	Do.
San Francisco [2 3]	29.95	−0.01	30.14	30th	29.74	20th.
San Diego [2 3]	29.90	−0.01	30.03	7th	29.79	31st.

[1] P. m. observations only.
[2] A. m. and p. m. observations.
[3] Corrected to 24-hour mean.
[4] Twenty-eight days.
[5] Twenty-nine days.
[6] Also on 31st.

The weather at Honolulu was close to normal; the mean temperature of 79° was only slightly above, as was the precipitation, 1.30 inches. The total rainfall from January to August was 6.59 inches, and the accumulated deficit for the period amounted to 11.38 inches. Winds continued easterly and the maximum velocity was 34 miles from the east, on the 22d. This may be compared with the extreme August velocity of 36 miles in 1908.

Several tropical storms occurred. Most of the information the Weather Bureau has at hand about those of the Far East is embodied in the attached report by the Rev. José Coronas, of the Philippine Weather Bureau. It may be added of the first typhoon described in this report, and noted as being lost sight of after passing Shanghai on the 16th, that according to the Tokyo Weather Charts it crossed the Yellow Sea and entered the continent to the northward on the 17th, thence disappearing in southwestern Manchuria.

On the 17th to the 19th a storm which became violent on the 18th was experienced by the American steamer *West Carmona* near 38° N., 150° E. The highest force of the wind was 11, east-southeast, lowest pressure 29.38. At this writing it is impossible to say whether the storm was of tropical origin or whether it developed near the place where it was reported by the *West Carmona*.

In the American Tropics two cyclones occurred, neither developing hurricane strength, so far as known. The first seems to have been brewing as early as the 8th, near 12° N., 96° W., at which time and place the American steamer *Victorious*, Panama to Honolulu, reported "wind shifting all around the compass, then back to NE." On the 11th, near 15° N., 109° W., the vessel encountered moderate gales, with somewhat depressed barometer. Pressure fell slowly until the 15th, when the lowest reading, 29.44, was made, as shown in Table 1. The highest wind force was 10, on the same date. Heavy rain squalls occurred through the week of the disturbance. The *Victorious* continued in the storm area, running nearly in the course of the cyclone until the 16th, the vessel then being at Greenwich mean noon in 17° 33′ N., 125° 40′ W., pressure still low, at 29.72, wind from the south, indicating that what remained of the cyclone still lay to the westward. Dense fog accompanied the storm on the 17th.

The second disturbance of this region occurred on the 22d–23d near where its predecessor was lost sight of a week previously. The lowest observed pressure was 29.60, near midnight of the 22d, highest wind force 9 from the east, in 18° 38′ N., 125° 36′ W., as reported by the American steamer *Volunteer*.

TYPHOONS AND DEPRESSIONS

ONLY TWO SEVERE TYPHOONS IN THE FAR EAST DURING AUGUST, 1926

By Rev. José Coronas, S. J.

[Weather Bureau, Manila, P. I.]

This month of August has been rather remarkable for the lack of severe typhoons. There have been none over the Philippines. And even in the whole Far East there have been only two intense typhoons but of no great extension. As they were both of a similar character so they followed also similar tracks.

The first typhoon appeared on the 12th over the Pacific about 250 miles east of northern Luzon between 126° and 127° longitude E. and near 17° latitude N. It probably moved north on the 12th and north-northwest from the 13th to the 16th. In the afternoon of the 14th the center passed near to the west of Ishigakijima (in the Meiacosima group of islands) where the barometer had fallen at noon to 735.5 mm. (28.96 inches) with a whole gale from the northeast. We do not know the barometric minimum, which must have been observed in the afternoon of the 14th. The typhoon entered China in the afternoon of the 15th near 121° longitude E. and 28° latitude N. It passed west of Shanghai in the morning of the 16th, moving still north-northwest. It is not possible with the data on hand to decide whether it continued moving north-northwest after passing west of Shanghai or whether it recurved northeastward. [See preceding article.] The steamer *President Hayes* felt the influence of this typhoon on the 15th over the northern part of Formosa Channel.

The other typhoon was formed on the 20th about 200 miles east of northern Luzon, between 125° and 126° E. longitude and near 17° N. latitude. It moved to the north on the 20th and 21st and in the morning of the 22d, and to the north-northwest in the afternoon of the 22d and on the 23d. The center passed over the Meiacosima group in the early hours of the 23d. The barometric reading at Ishigakijima was 741 mm. (29.17 inches) at 6 a. m. of that day, the winds blowing at that time with hurricane force from the south. The typhoon entered China in the morning of the 24th, moving west-northwest, but recurved to the north in the afternoon of the same day and to north-northeast on the 25th, the center passing the west of Shanghai in the afternoon of that day. In the early morning of the 27th the typhoon was over the northern part of Korea, moving northeastward.

DETAILS OF THE WEATHER IN THE UNITED STATES

GENERAL CONDITIONS

Two tropical cyclones passed inland, one over the Louisiana coast the other over the east Florida coast. Neither storm exhibited great energy after passing the coast line. The month as a whole was warm; rainfall was heavy in the Lower Lake region and the Ohio Valley, and normal or slightly above elsewhere, except in South Carolina, New Mexico, Oklahoma, and in parts of adjoining States where drought continued. The usual details follow.—*A. J. H.*

CYCLONES AND ANTICYCLONES

By W. P. Day

Thirteen disturbances were sufficiently definite to be followed for a few observations or more. Most of these took form over the northern Rocky Mountain region and moved slowly eastward without gaining more than slight intensity. Two disturbances, however, were of tropical origin and developed hurricane intensity over a considerable portion of their respective paths. One of these moved northward just west of Bermuda and was last noted as it passed over Newfoundland with somewhat diminished intensity. A barometer reading of 28.90 inches was reported southwest of Bermuda on the morning of the 6th. The other storm struck the extreme southern Louisiana coast on the evening of the 25th with barometer readings as low as 28.31 inches.

Ten high-pressure areas were plotted. One of these cool-air masses, pushing southward along the coast from eastern Canada, encountered a disturbance off Hatteras, whereupon a long cool rainy spell developed along the Middle Atlantic coast from the 18th to the 22d.

FREE-AIR SUMMARY

By L. T. SAMUELS

In Table 1 the temperature departures for the month are inappreciable except for the highest levels, where a marked tendency toward plus departures occurs at all stations. Relative humidity departures were mostly small and those of vapor pressure were likewise of no special significance, the latter being in general of the same sign as those for temperature.

In Table 2 the resultant winds for Ellendale exhibit the most pronounced departures from normal. At this station there was a decidedly greater south component together with a higher resultant velocity than normally, particularly in the higher levels.

An exceptionally striking example of a very deep and strong ascending air current occured at Ellendale on the 12th when the kite carrying the meteorograph became detached from the kite wire and immediately rose from an altitude of 1,750 meters to 4,900 meters above ground. The kite and instrument, together weighing approximately 18 pounds, rose as a free body throughout this 3-kilometer air column at the rate of 6.5 meters per second. The descent was at the rate of 4 meters per second. If we assume the effect of gravity alone and no descending current acting upon the falling kite, it is evident that the rate of the ascending current was approximately 10.5 meters per second. The meteorogram reveals a saturated condition throughout this air column and a temperature inversion at its top. The following is taken from the report of the official in charge at Ellendale:

A most unusual and exceedingly interesting action of the kites followed the breakaway on the 12th. The kites were being held at 2,200 meters awaiting the outcome of a thunderstorm cloud which had developed to the north and was spreading out toward the east and southeast. It appeared at first that our kites would be only in the extreme western edge of the rain area; however, the cloud built up toward the west and enveloped the kites more than was expected. When it became apparent that we could not wholly escape the storm, we started to reel in. Three kites were flying, two above the clouds and at a high angle. The record shows the head kite was at an altitude of approximately 1,600 meters at this time. We had reeled in for seven minutes under a fluctuating pull, which reached 350 pounds when the break occurred. During the interval of reeling in the surface wind had veered sharply to N. from SSE., the wind aloft remaining unchanged. At 4:49 p. m. the break, or rather the two breaks, came in quick succession. The upper section of the kite wire, between the second and third kites, was evidently struck by a mild lightning discharge, for it was found blackened and distempered later. This weakened it so that a break occurred at about 1,000 meters releasing the two lead kites in a westerly wind. The lower kite now being free from the others, shifted into the north wind. The shift took place so abruptly that with the sudden release from the other kites slack was thrown in the wire, forming a kink near the reel where the second break occurred when the wire again became taut. This last kite, trailing over 600 meters of wire, then moved off toward the south and southwest and finally caught on a telegraph wire about 2 miles to the southwest of the station. From this mooring the wire lay across a high tension line carrying 13,200 volts. When we reached the place long sparks were shooting up the kite wire whenever it touched two of the high-voltage wires. The kite wire was soon burned through and the kite came to the ground. This kite and wire were then recovered and taken back to the station.

Upon our return to town a telephone call had come in from the east that a kite was about 15 miles ENE. of the station. We made a trip out after it the same evening over exceedingly muddy and rough roads, made so by the heavy rain which fell east of the station during the thunderstorm. This kite, the first secondary, with most of the remaining wire, was recovered the same evening. Darkness soon prevented further search for the lead kite that evening. It was recovered the next day about 4 miles *west* of where the other secondary was picked up.

The meteorograph record shows a most unusual action of the head kite immediately following the breakaway. The upper section of the kite wire after being struck by the mild discharge broke at about 1,000 meters. It is not definitely known, as the kites were above the clouds, but conditions point toward the fact that the lead kite was at this time separated from the secondary, the break occurring at the swivel splice. This break was also apparently caused by weakened wire from the lightning discharge. The record shows that immediately after the break the instrument kite was actually sucked upward through the air and within a few minutes had reached an altitude of over 4,900 meters. This is by far the most amazing phenomenon I have ever encountered in connection with kite flying. Tremendous convection currents must have prevailed to cause such an ascent, for so long a period and through so much space, of an 18-pound kite and instrument. The record itself is unquestionable, both the pressure and temperature traces being quite true to form. The extreme height reached by the free kite was considerably more than twice that possible from the amount of wire out during the flight.

(Signed) L. A. WARREN, *Meteorologist.*

The data of this flight are given in the following table:

Time p. m.	Altitude (m) M. S. L.	Temperature	$\frac{\Delta t}{100\ m.}$	Relative humidity	Vapor pressure	Wind	
						Direction	Velocity
		°C.			mb.		m. p. s.
3:23	444 (surface)	22.4		67	18.16	SSE	5.8
	500	21.9		68	17.88	SSE	6.0
	750	19.3		75	16.80	SSE	6.9
3:33	783	18.8	1.06	76	16.50	SSE	7.1
	1,000	16.4		81	15.11	S	6.9
4:10	1,157	14.7	1.10	84	14.05	SSW	6.8
	1,250	14.2		89	14.42	SSW	7.7
4:14	1,296	13.9	0.58	92	14.62	SSW	8.1
	1,500	13.0		77	11.53	SSW	8.7
4:22	1,845	11.6	0.42	65	8.88	SW	9.7
	2,000	10.4		87	10.97	WSW	11.0
4:28	2,043	10.1	0.76	93	11.49	WSW	11.3
4:44	2,199	9.2	0.58	93	10.83	W	11.1
	2,500	7.9		93	9.90	W	
	3,000	5.9		94	8.72	W	
	3,500	3.8		95	7.62	WSW	
	4,000	1.7		96	6.62	WSW	
	4,500	−0.4		96	5.67	WSW	
4:54	4,908	−2.1	0.42	97	4.99	WSW	
	5,000	−1.5		97	5.24	WSW	
4:55	5,279	0.4	−0.67	97	6.10	WSW	
4:56	5,331	0.3	0.19	97	6.05	WSW	

It will be noted that the lapse rate from the ground to 1,157 meters (M. S. L.) exceeded the adiabatic for dry air while that *within* the cloud through which the breakaway kite was carried upward equaled the adiabatic rate for saturated air at the existing temperatures and pressures. It is evident that the convection in this case was extremely pronounced throughout an unusually deep layer, and although the lapse rates were sufficient to induce convection yet they were not greatly in excess of the respective adiabatic rates. This, however, should be expected from the fact that the observations represent conditions *within* the ascending column, whereas the lapse rates existing just previous to the vertical movement of the air in this region were probably even greater than those observed. While only a trace of rain fell from this storm at Ellendale it will be seen from Mr. Warren's report that *heavy* rain fell just east of the station.

Altitude (m.) M. S. L.	26th			27th		
	Temperture	Wind		Temperature	Wind	
		Direction	Velocity		Direction	Velocity
	°C.		m. p. s.	°C.		m. p. s.
141 surface	19.8	N	4.5	19.5	SSE	8.0
250	18.8	NNE	12.7	18.7	SSE	8.3
500	19.3	NE	13.6	16.9	S	9.1
750	17.6	NE	13.9	16.1	S	11.7
1,000	15.8	NNE	14.2	15.6	SSE	14.5
1,250	16.6	NNE	16.3	14.7	SSE	16.5
1,500	17.8	NNE	17.6	13.8	SSE	18.2
2,000	16.3	NNE	16.8	12.9	S	18.4
2,500	13.4	NE	15.4	12.7	SSW	19.2
2,723	12.1	NE	14.8	11.6	SSW	19.5

In connection with the tropical hurricane which reached the Louisiana coast on the 26th, the free-air

temperatures of the 26th and 27th over Groesbeck are a prominent feature. On the 26th this station was under the influence of the western quadrant of this disturbance, while on the 27th the center had passed just to the west of Groesbeck. Accordingly, the winds at Groesbeck on the two dates were from practically opposite directions. It is of special interest that the free-air temperatures were appreciably lower on the 27th when the winds were southerly than on the 26th when they were northerly. Wind velocities were strong on both dates.

At Broken Arrow on the morning of the 27th an ESE. wind of 21 meters per second prevailed at 3,000 meters above ground. Although the disturbance had almost disappeared so far as *surface* winds and pressures indicated, yet steep temperature and pressure gradients evidently persisted at this elevation.

Also in connection with this storm the afternoon pilot-balloon observation at Groesbeck on the 25th, when the hurricane was approaching the Louisiana coast, revealed steady increasing northeasterly winds to nearly 6,500 meters, by which time the balloon was carried beyond the range of vision. Ci. St. clouds, however, at a higher elevation were moving from the south. This is significant in view of the path of the hurricane and also because clouds of the same type at Broken Arrow, some 300 miles to the north, were simultaneously moving from the north-northwest.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during August, 1926*

TEMPERATURE (° C.)

Altitude, m. s. l. (meters)	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		*Washington, D. C. (7 meters)
	Mean	Departure from 9-year mean	Mean	Departure from 6-year mean	Mean	Departure from 9-year mean	Mean	Departure from 8-year mean	Mean	Departure from 9-year mean	Mean
Surface	27.7	+0.7	27.2	+1.1	19.3	−1.1	27.0	0.0	24.2	+0.4	25.5
250	27.5	+0.6	26.8	+1.1			26.0	−0.1	24.0	+0.4	24.8
500	25.7	+0.2	24.5	+1.3	19.0	−1.2	24.0	−0.3	22.4	+0.9	23.8
750	24.3	0.0	22.6	+1.1	18.0	−1.3	22.5	−0.7	21.0	+1.2	22.7
1,000	23.0	0.0	21.0	+1.1	17.2	−1.1	21.2	−0.9	19.4	+1.2	21.5
1,250	21.5	0.0	19.6	+1.2	16.3	−0.8	20.2	−0.6	18.1	+1.4	19.9
1,500	20.1	+0.2	18.2	+1.3	15.4	−0.3	19.2	−0.2	16.5	+1.2	18.4
2,000	17.2	+0.8	15.6	+1.6	13.2	+0.4	16.7	+0.2	13.8	+1.3	15.7
2,500	14.4	+1.4	12.9	+2.0	10.5	+0.6	14.3	+0.6	11.0	+1.1	12.6
3,000	11.3	+1.5	10.1	+2.1	7.5	+0.5	12.1	+1.0	7.8	+0.7	9.8
3,500	8.6	+2.2	7.6	+2.6	4.3	+0.2	9.7	+1.1	5.9	+1.5	6.7
4,000	5.8	+2.4	5.0	+3.3	1.2	0.0	8.4	+2.4	3.9	+2.0	3.1
4,500	2.8	+2.6	2.8	+3.7	−1.5	+0.4			2.5	+2.7	
5,000			1.0	+3.7	−2.6	+1.7					

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during August, 1926*—Continued

RELATIVE HUMIDITY (%)

Altitude, m. s. l. (meters)	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		*Washington, D. C. (7 meters)
	Mean	Departure from 9-year mean	Mean	Departure from 6-year mean	Mean	Departure from 9-year mean	Mean	Departure from 8-year mean	Mean	Departure from 9-year mean	Mean
Surface	65	0	73	+5	72	+7	74	+1	73	+7	79
250	65	0	73	+5			76	+2	73	+7	77
500	65	+2	74	+3	71	+7	78	+3	72	+6	75
750	65	+4	75	+3	66	+6	76	+6	72	+5	72
1,000	63	+3	74	+1	62	+4	74	+10	74	+6	69
1,250	61	+1	74	+1	60	+3	67	+5	73	+5	69
1,500	59	−1	71	−1	57	0	62	+1	73	+6	69
2,000	59	−3	61	−7	51	−4	60	0	69	+6	72
2,500	54	−8	59	−8	51	−3	56	−2	65	+7	76
3,000	57	−4	58	−9	53	0	49	−6	62	+9	68
3,500	55	−5	54	−13	55	+4	37	−11	57	+8	67
4,000	53	−7	52	−16	57	+6	13	−25	55	+5	70
4,500	53	−6	53	−14	58	+8			67	+15	
5,000			44	−14	59	+11					

VAPOR PRESSURE (*mb.*)

Surface	23.79	+0.99	25.89	+3.21	15.91	+0.83	25.99	+0.62	21.66	+2.34	25.76
250	23.62	+0.99	25.47	+3.13			25.27	+0.69	21.48	+2.37	24.42
500	21.34	+1.04	22.79	+2.80	15.34	+0.63	23.03	+0.73	19.16	+2.27	22.96
750	19.48	+1.19	20.67	+2.39	13.32	+0.25	20.59	+1.24	17.60	+2.14	20.37
1,000	17.50	+0.83	18.59	+1.89	11.80	−0.01	18.42	+1.69	16.49	+2.21	18.13
1,250	15.51	+0.31	16.91	+1.76	10.81	+0.08	15.57	+0.62	14.97	+1.96	16.50
1,500	13.63	−0.16	14.93	+1.43	9.65	−0.09	13.39	−0.25	13.60	+1.94	15.07
2,000	11.27	−0.17	10.85	+0.34	7.46	−0.39	11.27	0.00	10.88	+1.76	13.28
2,500	8.53	−0.62	8.73	+0.20	6.16	−0.21	9.13	−0.12	8.45	+1.56	11.28
3,000	7.45	+0.24	7.02	+0.07	5.20	−0.03	7.10	−0.39	7.48	+2.26	8.28
3,500	6.88	+1.26	5.44	−0.18	4.25	+0.03	5.12	−0.65	5.94	+1.97	6.52
4,000	6.46	+2.04	4.29	−0.36	3.50	+0.02	3.61	−0.51	5.42	+2.02	5.13
4,500	6.06	+2.74	3.75	−0.20	2.73	−0.10			5.97	+3.26	
5,000			2.69	−0.20	2.30	0.00					

* Naval air station.

TABLE 2.—*Free-air resultant winds (m. p. s.) during August, 1926*

Altitude, m. s. l. (meters)	Broken Arrow, Okla. (233 meters)				Due West, S. C. (217 meters)				Ellendale, N. Dak. (444 meters)				Groesbeck, Tex. (141 meters)				Royal Center, Ind. (225 meters)				Washington, D. C. (34 meters)	
	Mean		9-year mean		Mean		6-year mean		Mean		9-year mean		Mean		8-year mean		Mean		9-year mean		Mean	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	S. 7°W.	2.5	S. 2°W.	3.4	S. 70°W.	2.4	N. 72°W.	0.2	S. 56°E.	1.6	S. 23°W.	0.8	S. 13°W.	3.2	S. 15°W.	3.0	S. 5°E.	0.9	S. 55 W.	1.2	N. 79°W.	0.5
250	S. 11°W.	2.6	S. 2°W.	3.6	S. 71°W.	2.6	N. 83°W.	0.4					S. 10°W.	4.2	S. 16°W.	4.1	S. 31°W.	1.7	S. 58°W.	1.5	N. 67°W.	1.5
500	S. 18°W.	3.9	S. 12°W.	5.2	S. 70°W.	4.2	N. 74°W.	0.7	S. 45°E.	2.1	S. 18°W.	1.3	S. 19°W.	5.5	S. 22°W.	2.4	S. 45°W.	2.4	S. 63°W.	3.2	N. 61°W.	3.6
750	S. 22°W.	3.7	S. 19°W.	5.7	S. 70°W.	4.6	N. 73°W.	1.0	S. 20°E.	4.4	S. 26°W.	2.6	S. 23°W.	6.1	S. 21°W.	6.0	S. 54°W.	3.0	S. 72°W.	4.2	N. 60°W.	5.0
1,000	S. 28°W.	3.4	S. 27°W.	6.0	S. 75°W.	4.9	N. 73°W.	1.0	S. 6°E.	2.8	S. 40°W.	2.6	S. 22°W.	6.3	S. 20°W.	5.9	S. 59°W.	3.2	S. 77°W.	5.1	N. 66°W.	4.9
1,250	S. 31°W.	3.3	S. 33°W.	5.6	S. 78°W.	5.3	N. 79°W.	1.5	S. 20°W.	2.7	S. 50°W.	3.0	S. 21°W.	5.6	S. 20°W.	5.4	S. 74°W.	2.9	S. 82°W.	5.7		
1,500	S. 38°W.	3.4	S. 40°W.	5.5	S. 76°W.	6.5	N. 83°W.	2.3	S. 35°W.	3.0	S. 61°W.	3.6	S. 19°W.	4.9	S. 16°W.	4.8	S. 89°W.	4.3	S. 87°W.	6.5	N. 83°W.	5.1
2,000	S. 45°W.	2.8	S. 45°W.	5.0	S. 75°W.	8.9	N. 81°W.	3.2	S. 58°W.	4.6	S. 75°W.	4.8	S. 26°W.	3.7	S. 9°W.	4.0	N. 80°W.	5.6	S. 89°W.	7.5	N. 80°W.	8.0
2,500	S. 76°W.	2.6	S. 50°W.	5.0	S. 69°W.	9.3	N. 81°W.	3.9	S. 73°W.	7.5	S. 86°W.	8.6	S. 22°W.	4.0	S. 10°W.	4.0	N. 81°W.	6.4	N. 86°W.	8.8	N. 78°W.	8.9
3,000	S. 47°W.	1.2	S. 48°W.	5.4	S. 76°W.	10.3	N. 85°W.	5.3	S. 74°W.	10.8	W.	8.7	S. 34°W.	3.3	S. 15°W.	3.9	N. 69°W.	8.3	N. 84°W.	10.7	N. 78°W.	10.2
3,500	N. 72°W.	5.3	S. 45°W.	6.7	S. 83°W.	12.6	S. 88°W.	8.2	S. 72°W.	12.5	N. 85°W.	11.3	S. 59°W.	3.5	S. 16°W.	4.8	N. 64°W.	14.6	N. 84°W.	11.4	N. 77°W.	12.6
4,000	N. 23°W.	13.0	S. 51°W.	7.7	S. 65°W.	11.1	S. 88°W.	9.2	S. 69°W.	13.9	N. 83°W.	11.7	S. 22°W.	13.0	S. 7°W.	4.6	N. 56°W.	15.2	N. 84°W.	12.8	N. 88°W.	11.2
4,500	N. 23°W.	13.0	S. 58°W.	7.1	W.	11.0	N. 87°W.	11.1	S. 74°W.	16.2	N. 84°W.	12.2					N. 65°W.	22.0	N. 80°W.	13.2	N. 81°W.	10.1
5,000					W.	11.0	S. 76°W.	14.5													N. 89°W.	9.9

THE WEATHER ELEMENTS

By P. C. DAY, In Charge of Division

PRESSURE AND WINDS

Aside from an unusually long rainy period over the middle portions of the country from the Great Plains eastward to the Atlantic coast during most of the second and the first few days of the third decade and a severe tropical storm that passed inland from the Gulf of Mexico over southern Louisiana on the night of the 25th–26th, weather conditions for the month were not materially different from those usually expected during the last month of summer.

Cyclones were mainly weak and frequently indefinite, and anticyclones of importance were confined mainly to the more northern districts and exerted no marked influence on the weather, though the frequent succession of moderate pressure changes brought agreeable variations in temperature over most parts of the country.

At the beginning the remnant of the severe tropical storm that had entered the United States near northern Florida on the morning of July 28 and had moved northwestward to the vicinity of Memphis, Tenn., and then recurved to the northeast was central over Indiana. Precipitation had occurred during the preceding 24 hours over much of the territory between the Mississippi River and Appalachian Mountains, the amounts being heavy in portions of the Ohio Valley and near-by areas. This storm moved to the lower St. Lawrence Valley during the following two days and brought additional precipitation over the area previously referred to as well as to much of the country to eastward. Only scattered precipitation, mostly from thunderstorms, occurred during the remainder of the first decade, save on the 2d, when heavy rains fell over a small area in extreme southwestern Arizona, particularly in the vicinity of Yuma, where much damage resulted to crops and irrigation equipment. Further damage resulted to crops later, due to impairment of irrigation facilities and inability to secure necessary water.

Near the beginning of the second decade low pressure and rainy conditions became established in the middle Mississippi Valley and adjacent areas and with local variations persisted in that region and generally to the eastward for many days; over large areas from eastern Nebraska, Kansas, and Oklahoma, to the Atlantic coast, precipitation occurred almost daily until early in the last decade. While rainfall during this period was mainly not heavy, still in certain localities, particularly in the Ohio and middle Mississippi Valleys, Great Lakes region, and Atlantic coast districts, it was heavy and locally damaging.

Unusually heavy precipitation occurred over extreme southern Florida on the 18th, more than 8 inches falling at Key West within less than three hours, the heaviest fall in so short a period ever known there.

General and frequently heavy rains occurred over much of the country from the Mississippi Valley eastward near the middle of the last decade, and heavy precipitation was, as usual, associated with the severe tropical hurricane as it approached the middle Gulf coast on the 25th and 26th, 24-hour falls ranging from 5 to 15 inches being reported at points near the storm center. This storm was attended by high winds near the coast, with much damage to property and some loss of life, a full description of which will be found elsewhere in this issue.

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Except as noted above, the last week of the month was mainly without important cyclonic activity and little precipitation occurred.

The pressure distribution was not greatly different from that usually expected in August save that the monthly averages were slightly higher than usual over most of the United States and Canada. A small area in the far Northwest had averages slightly below normal, as did portions of the central valleys where precipitation was so persistent near the middle period of the month.

The average pressure was nearly everywhere higher than in July preceding. This is usually to be expected over the northern half of the country from the Rocky Mountains eastward, but in the South and far West average August pressures are usually lower than those for July.

The gradient between the areas of highest and lowest average pressures were not sufficient to greatly influence the prevailing wind directions, but these were mainly from southerly points except along the Pacific coast where they were chiefly from the Northwest.

Wind and hail storms were less frequent and damaging than in July, although high winds attended the tropical hurricane in the middle Gulf section.

Full details of the more important storms of the month appear in the table at the end of this section.

TEMPERATURE

The unusual warmth that has been a prominent feature of the weather over the far West for many months continued during August, but to a less extent than in most preceding months, and gave some indications of a final break-up. At the same time the northeastern districts which have been as persistently cool showed evidences of a change to warmer, though coolness was still maintained in the more northeastern sections.

As a rule there were frequent changes in temperature so that uncomfortable warmth or coolness did not long persist, and while the month was mainly warmer than normal the excess was due rather to moderately warm nights than to excessively warm days, a condition which resulted in many instances from long periods of cloudy, rainy weather.

The averages by weeks were usually moderately close to the normal, save for that ending the 31st, which was distinctly warm over a large area composing the central-northern districts and correspondingly cool over a comparatively small area immediately to the southward.

The average temperatures were above normal over the greater part of the country, though only in a few instances were the departures of importance. In parts of the far Northwest it was the tenth consecutive month with average temperature above normal, and in portions of eastern Washington the month completed the warmest summer in more than 50 years.

Over most of Montana the month was slightly cooler than normal for the first time during the present year. On the other hand, small areas in the Lower Lake region had the first monthly averages above normal since January. The extreme northeastern districts continued cool, as in all months so far save January.

The warmer periods ranged from the 1st to 31st, depending upon location, though they occurred mainly during the first decade from the middle and southern Plains eastward to the Mississippi River and in the Northeast, near the beginning of the second decade over the Ohio Valley and to eastward, and about the middle of the

last decade from the Great Lakes westward and in the far Southwest.

Maximum temperatures reached 100° or slightly more at some time during the month in nearly all the States, the highest observed, 124°, occurring in California, with 118° in Arizona and 110° or higher in most of the other States from the Great Plains westward. Locally in Nebraska the maximum temperatures on the 25th were the highest ever observed in August.

The lowest temperatures were observed mainly toward the end of the month, though in Florida they occurred on the 4th and in the west Gulf States mostly on the 8th or 9th.

No freezing temperatures occurred over the important crop-growing districts, but readings below 20° were observed at a few high stations in Colorado and New Mexico, and most of the other mountain States had readings below freezing at elevated exposures.

PRECIPITATION

Over the more important agricultural districts the precipitation was mainly sufficient for crop needs, though portions of Kansas and near-by areas of other States suffered from drought during the first decade, and similar conditions existed in the far Northwest.

The month as a whole was dry over most of South Carolina, and in portions of eastern Georgia, northern Florida, southern Texas, and generally over the Southwest.

In the Ohio and middle Mississippi Valleys, Lower Lakes, and Middle Atlantic States precipitation occurred frequently, was generally well above the normal, and locally excessive; some stations reporting the monthly falls as the greatest ever measured in August. There were large excesses over southern Florida and along and near the Gulf coast from western Florida to Louisiana, the latter due mainly to the heavy rains attending the tropical storm near the end of the month.

The general absence of rains during the early part of the month favored the continuation of severe forest fires in the far Northwestern States, and these were largely unchecked until after the middle, when more or less important rains fell over wide areas.

RELATIVE HUMIDITY

Over practically all portions, from the Missouri and Mississippi Valleys eastward to the Atlantic coast, the relative humidity was mainly well above the normal, though the effect of drought in portions of the Southeast is well outlined by a corresponding area showing humidity below or only slightly above normal.

In the far West relative humidity was mainly above normal over northern districts, due largely to rather moist conditions existing in the latter part of the month. In the Southwest humidity was less than normal throughout the month, though the deficiencies were not large.

SEVERE LOCAL HAIL AND WIND STORMS, AUGUST, 1926

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.]

Place	Date	Time	Width of path	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
			Yards[1]					
Evansville, Ind. (12 miles southwest of).	3	P. m.		1		Electrical	No property damage reported; one person injured.	Official, U. S. Weather Bureau.
Purdum, Nebr. (8 miles northwest of).	3	6-7 p. m.			$2,500	Hail	Heavy damage over 140 acre field; other fields slightly injured.	Do.
Alta, Wyo.	3					Electrical	Nine cows and 57 sheep killed	Do.
Nogales, Ariz. (7 miles north of).	4	P. m.			600	Thunderstorm and hail.	Slight crop damage and 57 goats killed	Do.
Henry and adjacent counties, Ind.	4-6			3		Thunderstorms and winds.	Crops, buildings, and wires damaged	Do.
Ludington, Mich. (10 miles east of).	5	4-5 a. m.				Thunderstorm	One house burned and another damaged	Do.
Saginaw, Detroit, and Flint, Mich.	5	A. m.				Electrical	Much damage to wire systems and farm buildings; traffic impeded.	Times (Detroit, Mich.); Grand Rapids Press (Mich.).
Frankfort, Ind. (near)	5					Heavy hail	Moderate crop damage reported	Official, U. S. Weather Bureau.
Mahoning County, Ohio	5					do	Character of damage not reported	Do.
Mayville, N. Dak.	5					Severe hail and wind.	Thirty thousand bushels of small grains destroyed; windows broken.	Do.
Chacon, N. Mex. (near)	6	2-4 p. m.				Severe hail	Crops damaged	Do.
Lenawee County, Mich.	6	5-6 p. m.			100,000	do	Thousands of acres of crops destroyed, fruit trees injured; wires blown down; many chickens and ducks killed.	Do.
Erie County, N. Y., northeastward to Adirondack Mountains.	6					Thunderstorms, wind and rain	Buildings, telephone and power lines damaged; crops injured; some hail reported at Oswego.	Do.
Fulton and Henry Counties, Ohio.	6					Destructive hail	Character of damage not reported	Do.
Petersburg, Ill.	6					Wind and hail	Several buildings damaged	Do.
Salem, Ill.	6	3 p. m.	440-1,760		17,000	Hail	Fruit and other crops damaged over path 6 miles long.	Do.
Tippecanoe City, Ohio (2 miles south of).	6				5,000	Electrical	Barn destroyed	Do.
Ville Platte, La.	7	2 p. m.	440		2,750	Wind	Timber, crops, and buildings damaged	Do.
Pleasantview District, Oneida County, Idaho.	8					Hail	Many acres of wheat destroyed	Tribune (Pocatello, Idaho).
Cherry, Boyd, Holt, Knox, and Antelope Counties, Nebr.	9	5-7 p. m.	30 mi.		150,000	Wind, rain, and hail.	Many farm buildings wrecked; crops injured; trees uprooted. Path 120 miles long.	Official U. S. Weather Bureau.
Rawlins County, Kans. (northeast part of).	9	8 p. m.			2,500	Tornado	Damage chiefly to barns and outbuildings	Do.
Rawlins County, Kans.	9	8-10 p. m.				Hail	Minor damage as most staple crops had matured. Path several miles wide.	Do.
Watson, Utah	9				2,000	do	Trees and shrubbery stripped; windows broken and roofs pierced.	Do.
Padroni, Colo. (near)	10	P. m.		1		Tornado	Two houses demolished, other buildings, several autos, and farm machinery destroyed or badly damaged. Three persons injured.	Daily Sentinel (Grand Junction, Colo.).

[1] "Mi." signifies miles instead of yards.

Severe local hail and wind storms, August, 1926—Continued

Place	Date	Time	Width of path	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
			Yards					
Salina, Kans. (near)	10	P. m.				Dust whirls	Some damage to barns and small buildings. Whirls had many characteristics of a tornado.	Official, U. S. Weather Bureau.
Burns, Wyo.	10				18,000	Hail and wind	Path covered about 20 sections, crops damaged about 25 per cent.	Do.
Kewanee, Ill. (near)	10		3,520			Hail	Considerable damage over an area 1 mile square.	Do.
Meeker, Colo.	10					Destructive hail	Gardens injured; auto tops pierced.	Do.
Atlanta, Ga.	11	11 a. m.			20,000	Wind and hail	Considerable damage in low sections by flooding; several houses struck by lightning; 1,000 telephones out of order.	Do.
Salem, S. C.	11	P. m.		1		Thunderstorm	Two men injured; no property damage reported.	Do.
Carlinville, Ill.	11	8:20 p. m.				Wind and hail	One barn and several chimneys blown over.	Do.
Columbiana County, Ohio.	11					Destructive hail	Character of damage not reported.	Do.
Manti, Wash.	11					Hail	Fruit and standing grain injured.	Do.
Lusk, Wyo.	12	1:15–1:45 p. m.				Tornado	Haystack and some wiring damaged. Path 4 miles long.	Do.
Hartford, Conn., and vicinity.	12	P. m.		1		Violent electrical	Many fires started by lightning; traffic impeded; overhead wire systems damaged.	Hartford Courant (Conn.),
Hingham, Mont. (north of).	12	do.				Hail	Heavy local crop loss.	Official, U. S. Weather Bureau.
Ionia County, Mich.	12				27,000	Electrical	Six barns and a church burned.	Grand Rapids Press (Mich.)
Lower Hudson and New York Bay district.	12			1	500,000–1,000,000	Thunderstorm, wind, and rain.	Subways and rail lines paralyzed; many buildings struck by lightning; many persons injured; much property damage by flooding.	Official, U. S. Weather Bureau; Herald Tribune (N. Y.).
Toulon, Ill. (near)	12					Electrical	Barn burned, 1 horse and 7 hogs killed.	Official, U. S. Weather Bureau.
Washington County, Md. (eastern part of).	12	P. m.			5,000	Wind	A number of barns unroofed; trees uprooted.	Do.
Hulett, Wyo.	13	1 a. m.	1,760		500	Tornado	Crops damaged. Path 3 miles.	Do.
Boone, Story, Polk, and Van Buren Counties, Iowa.	13	P. m.				Hail	Buildings, crops, and orchards damaged.	Do.
Castle Rock, Colo. (near)	13					do	Crops damaged.	Do.
Haswell, Colo.	13					do	Crops destroyed on several ranches.	Do.
Monmouth, Ill. (near)	13		3,520			Heavy hail	Damage severe; fruit ruined.	Do.
New York City, N. Y., and vicinity.	14	A. m.				Thunderstorm, wind, and rain.	Many trees uprooted; traffic impeded; buildings damaged; roads inundated.	American (New York).
Shadyside, Ohio.	14	1:50 p. m.			31,000	Probably tornado	Building and contents damaged; 8 persons injured.	Official, U. S. Weather Bureau.
Minneapolis, Minn.	15	9:35 a. m.				Wind and rain	Wire systems damaged; much inconvenience resulted from traffic interruption.	Do.
Hollis, Okla.	15	4 p. m.	1,760			Hail	Considerable crop damage in some sections. Path 8 miles.	Do.
Charles Mix County, S. Dak., Geddes to Milwaukee.	15	P. m.			50,000	Wind	Much damage to business houses.	Tribune (Sioux City, Iowa).
Roy, N. Mex. (near)	16	2:30 p. m.	3,500			Heavy hail	Considerable crop loss.	Official, U. S. Weather Bureau.
Fremont County, Iowa.	16	8. m.				Hail	Crops damaged 25 per cent.	Do.
North shore Long Island, N. Y.	16				200,000	Wind and waterspout.	Six houses wrecked and many others damaged; many trees in Glen Cove and Sea Cliff uprooted.	Official, U. S. Weather Bureau; Herald (New York).
Ridgefield and Morsemere into Palisade, N. J.	16	6:45 p. m.	33		50,000	Tornado	Some structures totally destroyed, others damaged; many trees uprooted.	Official, U. S. Weather Bureau.
Sparta, Ill.	16				1,000	Electrical	School building struck; several persons shocked.	Do.
Wilson, Ark. (near) into Miss.	17	6:15 p. m.	100	2	15,000	Tornado	Considerable property damage; 11 persons injured.	Do.
LeMars (south of) to Marcus, Iowa.	17	8 p. m.	880			do	A few buildings wrecked; crops damaged 50 per cent.	Evening Tribune (Des Moines, Iowa).
Wellington, Kans.	18	12:40 p. m.			1,500	Hail	Gardens and truck damaged.	Official, U. S. Weather Bureau.
Gillette, Wyo. (13 miles north of).	18	6 p. m.	50		200	Tornado	Minor damage. Path 10 miles.	Do.
Carroll and Mitchell Counties, Iowa.	18	P. m.				Hail	Much destruction in places.	Do.
O'Neill, Nebr.	19	2 p. m.	1,760			do	Damage severe in places.	Do.
Wray, Colo.	19	4 p. m.	3 mi.		20,000	Hail and wind	Character of damage not reported.	Do.
Methow, Wash. (near)	19				7,000	Hail	Fruit injured.	Do.
Wonewoc, Wis. (3 miles south of).	20	Noon	167		1,000	Tornado	Small buildings damaged; crops flattened; 1 person injured. Path one-half mile long.	Capital Times (Madison, Wis.).
Charlotte, N. C.	20					Thunderstorm, wind and hail.	Considerable minor damage.	Official, U. S. Weather Bureau.
Wayne County, Iowa.	20	7 p. m.	1,760			Hail	Considerable damage over path 12 miles long.	Do.
Mitchell County, Iowa.	20	7:30 p. m.	3 mi.		50,000	do	Damage principally to crops. Path 3 miles.	Do.
Keokuk County, Iowa.	20	9 p. m.	3 mi.		8,000	do	Crops and fruits injured; windows broken.	Do.
Hobart, Okla., and vicinity.	21	5 p. m.	1,760		2,000	do	Some crop and other property damage reported. Path 4 miles.	Do.
East Lake Erie and vicinity	21			3		Gale	One steamer sunk; crop and property damage heavy in Erie and Dunkirk sections.	Do.
Buchanan County, Iowa.	23	2 a. m.			1,100	Hail and wind	Crops injured.	Do.
Grand Haven, Mich.	23					Wind and rain	Trees uprooted; tents blown over; plate-glass window broken and some telephones out of order.	Do.
Marengo, Ill. (near)	23					Electrical	Church destroyed.	Do.
Waterloo, Ill. (1 mile north of).	23					Wind	Poles of interurban line prostrated; traffic delayed.	Do.
Louisiana (eastern coast), Mississippi (southern part of).	25–26			25	6,000,000	Hurricane	Many buildings and contents damaged; heavy crop loss; telephone and telegraph companies sustain heavy losses; shipping delayed.	Do.
Washington (eastern part of).	25–26					Wind	Grain shattered; fruit blown off.	Do.
Big Fork, Mont. (near)	26	P. m.				High wind	Rural telephone lines down; roads obstructed.	Do.
Longs Peak, Colo.	29					Destructive hail	Character of damage not reported.	Do.
Wapello County, Iowa.	29		1,760		600	Wind and hail	Some property damage reported.	Do.
Bitter Root Valley, Mont. (eastern part of).	30					Hail	Some orchards severely damaged.	Do.
Lake Wales, Fla.	31					Electrical	Packinghouse damaged by lightning.	Do.

STORMS AND WEATHER WARNINGS

WASHINGTON FORECAST DISTRICT

From reports now available it is apparent that a disturbance of slight intensity moving on a WNW. course was about 500 miles northeast of Basseterre, St. Kitts, on the morning of the 1st. It then moved NW. with increasing intensity to a point about 250 miles S. by W. of Bermuda by the evening of the 5th, when the first definite indications were received in the report of falling pressure and increasing NE. winds at Bermuda. Information was broadcast at that time that the disturbance was apparently of considerable intensity and moving NNW. with the admonition that vessels north and northwest of the center should exercise caution. The storm (see track No. III, Chart II) moved northward and passed over Newfoundland, attended by winds of hurricane force. Warnings were broadcast twice daily. On the evening of the 7th there seemed to be some chance of gales off the Maine coast and storm warnings were displayed from Portland to Eastport, but strong winds were not reported from Maine coast stations.

Vessel reports received by mail show that the disturbance was of considerable intensity as early as the 1st, when the Dutch steamship *Bellatrix* encountered winds of force 11 and lowest pressure of 29.39 in latitude 22° 16′ N., longitude 56° 02′ W.

It was next encountered by the steamship *Baron Bellingham* in latitude 28° 43′ N., longitude 63° 20′ W., at noon of the 5th with a barometer reading of 28.94 inches and winds of hurricane force. At 5:30 p. m. of the 5th the hurricane passed near the steamship *San Gerardo* in approximately latitude 30° N., longitude 66° W., with lowest barometer reading 29.12 inches and force 12 from the north. At 6 a. m. of the 6th the steamship *Colorado Springs* in latitude 31° 25′ N., longitude 67° 37′ W., reported a barometer reading of 28.90 inches and force 12 from the north. Unfortunately, only the report of the *Colorado Springs* was received by radio. It assisted considerably in forecasting the progress of the storm.

On the 22d storm warnings were ordered for the Atlantic coast between Boston and Hatteras in connection with a disturbance of slight intensity east of Hatteras. This disturbance never advanced northward, but was held in check by the high pressure area on the north and slowly decreased in intensity; storm warnings were lowered the evening of the 22d.

On the 20th and 21st between Jamaica and the Yucatan Channel conditions were somewhat unsettled, and on the following day there were indications of a circulation on the extreme western coast of Cuba. It was not until the following morning that we had definite indications of the existence of a tropical disturbance. An observation taken at midnight of the 22–23d on board the steamship *Saramacca* in latitude 22° 42′ N, longitude 88° W., showed a pressure of 29.34 inches, northeast force 7, raining. Accordingly information was disseminated that the disturbance was at least of moderate intensity but small diameter. Subsequently it advanced at a rate of about 12 miles per hour to about latitude 25°, longitude 91°, and then turned northward, at a slower rate, estimated at 7 miles per hour, but with increasing intensity and extent.

On the morning of the 24th advices were issued stating that the hurricane was apparently recurving to the northward and would probably reach the coast somewhere between Galveston and Burrwood. In the afternoon of that date advices were disseminated to the effect that the storm was increasing in intensity and extent. At 10 p. m. of the 24th hurricane warnings were ordered from Morgan City, La., to Mobile, Ala., with the information that the disturbance was moving north-northeastward and that it would cross the eastern Louisiana coast attended by winds of hurricane force and high tides. Northeast storm warnings were ordered at the same time east of Mobile to Apalachicola and changed to northwest west of Morgan City to Galveston.

On the morning of the 25th the following bulletin was issued:

> Tropical disturbance increasing in intensity approaching eastern Louisiana coast. Every precaution should be taken in area affected taking into consideration extremely high tides that will probably occur between point where center strikes coast and Mobile. Steamship *Cranford* passed hurricane center 7.45 a. m. at approximately latitude 27° 40′, longitude 90° 40′.

The tropical disturbance passed inland in the late afternoon of the 25th (see Track No. VIII, Chart II) slightly east of Morgan City, La., and nearly over but immediately west of Houma. The lowest barometer at the latter being 28.31 inches between 9.30 and 9.55 p. m. of the 25th and at Morgan City 28.80 inches between 11.15 p. m. of the 25th and 12.30 a. m. of the 26th. The lowest reading at New Orleans was 29.37 inches at midnight and 1 a. m. of the 26th. Details regarding winds and tides in Louisiana and their effects are given under the report of the New Orleans district.

No seriously destructive effects of the storm were experienced on the Mississippi and Alabama coasts, although maximum tides of 3 to 4 feet or more above normal were reported from Mobile westward to the mouth of the Mississippi River. The lowest pressure at Mobile was 29.78 at 2 a. m. of the 26th with a maximum wind of 43 miles per hour.

This disturbance was of limited extent but of great intensity. The warnings were accurate, complete, and timely and the damage remarkably small. In the section around Berwick and Morgan City where the winds were severe, the losses were extremely small, as indicated by the following letter from the president and general manager of the Louisiana Oyster & Fish Co., dated August 28:

> On behalf of this company and the citizens of Morgan City and Berwick I wish to thank you for the splendid service rendered by your department during the past storm. Advices given by you made it possible to save much property and many lives.
>
> The writer received your phone message at 1 o'clock Monday morning. At 7 a. m. we had a fast boat on the way to the shrimping grounds and at 9 o'clock the word was passed around giving everyone outside in this vicinity plenty of time to get away from the coast. As a result, there was not a loss of life that we know of in that territory and no boats lost. The only boats lost here and at Morgan City were the property of those who refused to move their boats away from the front and put them in harbor. There were about 20 boats sunk here and none on this coast.

The vessel-reporting service functioned splendidly, numerous reports, both regular and special, being received. The steamship *West Quechee* passed through the center or "eye" of the hurricane, where the winds dropped from hurricane to force 4. The captain reports that at that time quantities of birds were encountered "so thick about the vessel that the second mate went on deck and literally scooped them up by the armful, carrying them into the deck house."

After crossing the coast the disturbance rapidly decreased in intensity. Within 24 hours the lowest pressure reported was 29.72 and highest wind 16 miles per hour, and in the following 12 hours it had disappeared. The rapidity with which intense tropical disturbances decrease in intensity after passing inland is truly remarkable.

The barometer readings at Morgan City and Houma furnish data from which some idea of the pressure gradient in this and other hurricanes may be obtained. The distance from Morgan City to Houma is approximately 29 miles. At 9:40 p. m. of the 25th, when the pressure was lowest at Houma, 28.31 inches, the pressure at Morgan City was about 28.97, a difference of 0.66 inch in a distance of 29 miles, or a gradient of 0.0228 inch per mile. However, the center passed west of Houma and east of Morgan City, thereby reducing the distance, as near as can be estimated, to 22 miles. Further, the pressure was undoubtedly lower at the center than at Houma, which would increase the difference between the pressure at Morgan City and that at the center a tenth of an inch on a conservative estimate, making the gradient 0.035 per mile.

While the present hurricane was severe it was neither of the extent nor development of some in other years. Unfortunately, only in a limited number of these disturbances have we authentic barometer readings from two stations properly located near the center. One of the most remarkable of these was the hurricane of September, 1919, which passed on a course about west-northwest, 30 or 40 miles south of Key West. Sand Key lies about 8 miles south of Key West. At both stations mercurial barometer readings are available, as follows: Lowest, Key West, 28.83 inches, and at Sand Key, 28.35 inches, a difference of 0.48 in 8 miles, or 0.06 inch per mile.—*R. H. Weightman.*

CHICAGO FORECAST DISTRICT

The temperature averaged above the normal over most of the forecast district, there being a slight deficiency in northern Michigan and western North Dakota only. The excess was considerable on the central Great Plains, where extremely warm weather prevailed on several days.

The distribution of rainfall was rather irregular, deficient in some portions and excessive in others. The largest rainfalls occurred in the Ohio Valley, Cairo having a total of 12.02 inches during the month. In consequence of the heavy rains, some areas in the central valleys were flooded.

Storm movement across the district was rather sluggish, but the area covered by rainfall was at times unusually extensive for the season.

The one disturbance attended by strong winds developed in the west near the close of the second decade. Its center reached Lake Michigan on the night of August 20 and passed over Lake Huron on the 21st and 22d. This storm was attended by rather strong winds and severe squalls on Lakes Huron, Erie, and Ontario; small-craft warnings were ordered for these lakes on the morning of the 20th and continued on Lakes Erie and Ontario on the 21st. Reports show that a small steamer, the *Harold S. Gerkin*, which left the city of Erie, Pa., on the morning of the 21st, was sunk 8 miles out in the lake. The ship carried a crew of 20 men, of whom 16 were known to be rescued.

No frost warnings of any kind were issued, and no frost occurred.

Special fire-weather forecasts were issued at times to the State and National Forest Service for the northern Michigan peninsula, and special fruit-spray forecasts to the orchardists in Door County, Wis., and southwestern lower Michigan.

The forecast center made special forecasts day by day for the annual commercial reliability tour of airplanes which started from Detroit August 7 and, after a tour of middle-western cities, returned to that place August 21, 1926. The tour started with 28 planes and finished at Detroit with 19 still in the race. (Special report was made on this work in letter of August 27, 1926.)—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT

The only warnings required were in connection with the tropical hurricane of August 23–26. Warnings were issued by the central office, as follows:

August 23, advisory, noon: Tropical disturbance of at least moderate intensity but small diameter in approximately latitude 23, longitude 88.

August 23: Hoist northeast storm warnings 10.30 p. m. New Orleans to Matagorda, Tex. Tropical disturbance of considerable intensity but small diameter moving northwest. Estimated position, latitude 25½, longitude 90½. Impossible to indicate where storm will strike coast, but interests should be prepared to take quick action on to-morrow morning's advices.

August 24, advisory, 10.30 a. m.: Tropical disturbance located approximately latitude 26, longitude 92, of considerable intensity but small diameter, apparently recurving to the northward, will probably reach the coast somewhere between Burrwood, La., and Galveston late to-night or early Wednesday morning. Area over which destructive effects will be felt will be small. Further advices this afternoon.

August 24, advisory, 5.30 p. m.: Nothing in reports received this afternoon to change this morning's advices, except that disturbance appears to be increasing somewhat in intensity and extent. In absence of reports near center, estimated position at 5 p. m., latitude 27, longitude 92. Further advices to-night.

August 24: Hoist hurricane warnings 10 p. m. Morgan City, La., to Mobile, Ala. Tropical disturbance moving north-northeastward, central about latitude 28, longitude 90½. Will cross eastern Louisiana coast line late to-night or early to-morrow morning. Northeast and east winds will increase to hurricane force by Wednesday morning, accompanied by high tides. Advise all interests that storm is increasing in energy and extent. Northeast storm warnings have been ordered east of Mobile to Apalachicola and storm warnings have been changed to northwest west of Morgan City to Galveston.

August 25, advisory, 9.30 a. m.: Tropical disturbance increasing in intensity approaching eastern Louisiana coast. Every precaution should be taken, taking into consideration extreme high tides that will probably occur between point where center strikes coast and Mobile. Steamship *Cranford* passed hurricane center 7.45 a. m. at approximately latitude 27°, 40′, longitude 90°, 40′.

August 25, 3.30 p. m.: Continue hurricane warnings 10 p. m. Morgan City, La., to Mobile, Ala. Tropical disturbance of great intensity near eastern Louisiana coast moving slowly north-northeast. Increasing northeast and east winds will reach hurricane force to-night. Winds will be dangerously severe and tides high. Every precaution should be taken.

August 25, advisory 9 p. m.: Tropical disturbance passing inland near and probably slightly east of Morgan City, La., moving north-northeastward, attended by dangerous shifting winds. No further advices this disturbance.

WEIGHTMAN.

The morning reports of the 26th showed that the storm had advanced inland to central Louisiana and had decreased greatly in energy. Warnings for this district were accordingly lowered soon thereafter.

This tropical disturbance, increasing in intensity as it slowly approached the eastern Louisiana coast, reached the coast in the afternoon of the 25th as a remarkably intense hurricane. When on the Louisiana coast it was about half as extensive as the great storm of September, 1915, but the barometric gradient within 50 miles of the center was fully as steep as in that storm. From reports of damage, the usual condition of strongest winds to the right of the center was fulfilled, but as intense storms of slow movement have less difference between wind velocity in the right and left segments than more rapidly moving storms, it is not surprising that winds of hurricane force occurred at Morgan City, which was to the left of the storm center and a few miles inland. West of Morgan City the wind velocity fell off rapidly, as shown by the effects of the storm.

Moving north-northwest, the storm passed inland over southern Terrebonne County, its center slightly west of the town of Houma, where the lowest barometer reading, corrected by bell jar comparison, was 28.31 inches, at 9:30–9:55 p. m. At Morgan City, 32 miles northwest of Houma, the lowest barometer reading, corrected in the same manner, was 28.80 inches, between 11:15 p. m. of the the 25th and 12:30 a. m. of the 26th. The maximum wind velocity at Morgan City, up to the time the anemometer became unserviceable, was 70 miles an hour from the northeast at about 10:30 p. m., with an extreme velocity within a period of 10 seconds, of 90 miles an hour. At New Orleans the lowest barometer reading was 29.37 inches at midnight and 1 a. m. of the 26th, and the highest wind velocity was 44 miles an hour from the southeast at 9:42–9:47 p. m. of the 25th, with an extreme velocity of 52 miles for the fastest mile, though gusts too brief to register had still higher velocities.

After passing between Thibodaux and Morgan City, the further course of the storm center was along or near the west bank of the Mississippi River to east-central Louisiana, where the storm had so greatly weakened by 7 a. m. of the 26th that the winds were no longer dangerous. The greater part of the damage occurred from New Orleans westward to Franklin and from Donaldsonville southward to the coast. In New Orleans the damage, estimated at $250,000, was principally due to fires where electric wiring was probably rendered defective by the winds, though there was considerable damage also to roofs of houses here and elsewhere in the storm-swept section.

An authentic, complete survey of the property losses has not been made but the probable loss is between $3,000,000 and $5,000,000, besides considerable damage to crops and trees. The Bureau of Agricultural Economics estimates that damage from the storm in percentage of normal crops for southern Louisiana, was about 8 per cent to sugar cane, 9 per cent to rice, 6 per cent to corn, 3 per cent to soy beans, and 14.7 per cent to pecans. Cotton, of which the acreage in this part of the State is small, suffered considerable damage also.

No vessel losses off the coast have been reported to this office. A number of small boats were sunk in harbor at Morgan City and in the Terrebonne section. In the Mississippi River a few river boats and barges, with cargoes went down.

Twenty-five persons are known to have lost their lives as a result of the storm, a few through contact with live wires, but nearly all from drowning on Felicity Island and near Gibson, both in Terrebonne County, and from the capsizing of a boat in the Mississippi River near Convent, La.

In general the tides were not remarkably high for a hurricane. In southeastern Terrebonne County, where the storm was most severely felt, the tide was 3 to 6 feet above normal over the marshes and streams, with one report of 15 feet above normal in a small locality about 30 miles south of Houma, while along the western Terrebonne coast the tide was near normal. The highest readings of the river gauge at Morgan City were only slightly above normal and reports from Burrwood indicated a storm tide of scarcely more than a foot. Considerable water accumulated in bayous and lakes around New Orleans but was not high enough to cause material damage or to delay train service on the Louisville & Nashville Railroad, the storm tide at Chef Menteur, northeast of New Orleans on this line, being about 4 feet. The Southern Pacific Railway and the Illinois Central suffered minor damage and delay of a day or two in train service.

The timely warnings resulted in the saving of much property and many lives. Boats and radiophone carried the warnings to Cameron Parish and through the Barataria Bay section to Grand Isle. The merchants of Houma, Morgan City, and other towns, through the aid of fishermen, sent the warnings to isolated sections of Terrebonne and St. Mary Counties. Interests concerned, mail, telegraph, telephone, and radio were utilized and with the able assistance of the daily newspapers, the warnings were well disseminated through the inland territory. The stations WSMB and WCBE of New Orleans and KPRC of Houston rendered valuable service and those of the Tropical Radio Co. and the United States Navy were very effective in behalf of marine interests and in collection of important weather reports from ships in the Gulf of Mexico.—*R. A. Dyke.*

DENVER FORECAST DISTRICT

The usual low-pressure conditions of summer prevailed over the Great Basin and southern Rocky Mountain regions during most of August; and during the first half of the month the Pacific Ocean high pressure extended well to the northeastward over the Alaskan coast and into western Canada. This distribution resulted in frequent light showers and thunderstorms in the central and southern mountainous regions of the district, and in dry weather in western Montana. On the morning of the 16th the Alaskan high pressure was replaced by a rather deep LOW that had moved eastward from the Aleutian Islands, and thereafter throughout the month low pressures prevailed over Alaska and western Canada. At times during this period offshoots of the Pacific HIGH overspread northern California and extended inland to the northern Rocky Mountain region, causing general rains over the Pacific northwest and in Montana and Wyoming, effectually breaking the drouth. When the pressure was not unusually high along the California coast and low pressure continued along the Canadian border, unusually high temperatures prevailed in Montana and Wyoming.

Daily forecasts of wind direction and velocity for western Montana were furnished for the benefit of the Forest Service in combating the serious forest fires in that region. No other warnings were required.—*E. B. Gittings, Jr.*

SAN FRANCISCO FORECAST DISTRICT

The barometer was high over the greater portion of the northeast Pacific Ocean during the early part of August, with pressure considerably above normal in the Gulf of Alaska. A movement of this anticyclone caused rising pressure over the North Pacific States and western Canada on the 5th and advices of warmer weather were issued for Oregon and Washington, which were duly amplified in the fire-weather warnings by officials in those States. Temperatures rose as predicted and remained generally above normal with low humidity until the 9th. Similar warnings were issued for northern California on the 5th and, although temperatures did not rise materially, the hazard in the forested areas increased and numerous fires started. In the Shasta National Forest, in the extreme northern end of the State, the situation became so acute that the forest supervisor asked for special advices daily. These were sent to him morning and evening until the fires were put under control. Similar daily service was given the Sequoia National Forest on the 17th, and for several days thereafter, to aid in the suppression of serious fires in that area.

On the 17th a radical change took place in the weather of the North Pacific States. The drought which had prevailed since the 19th of June was terminated by the southeastward movement of a low-pressure system from the valley of the Yukon. Rains and lower temperatures brought marked relief to the forest-fire situation in Oregon, Washington, and Idaho, a change in conditions which was anticipated 12 to 24 hours by district and local forecasts. Another disturbance of similar type produced general rains in the northern parts of the district on the 26th. Its behavior was unusual in that the rain in the north was preceded by showers in the coast range counties of California from the bay region northward, which, though light, were sufficient to require the covering of fruit in the process of sun-drying. Adequate warnings were issued to provide for protective measures.

On the 28th the first disturbance showing typical Fall characteristics appeared in the Gulf of Alaska, the pressure variation charts showing large changes on that and succeeding dates. This storm brought general rains to the North Pacific States and further relief to the fire situation in the forests. These rains were predicted 24 hours in advance.—*T. R. Reed.*

RIVERS AND FLOODS

By H. C. FRANKENFIELD

The floods of August were few and of very moderate character. The Trinity River of Texas was in moderate flood during the last week of July and crested on August 1 at a stage of 30.3 feet, 5.3 feet above the flood stage. The crest stage at Trinidad was 31.1 feet, or 3.1 feet above the flood stage, on August 5, but there were no floods below that point. A crest of 26 feet also occurred at Dallas immediately after the heavy rains of August 17–19. The floods were properly forecast and no losses of consequence occurred. These rains also caused moderate floods in the Sulphur River of Texas. Flood warnings were not necessary and no reports of damage were received. The excessive rains of August 16–18 over the upper drainage area of the Black River of Arkansas were followed by a flood that, while of small proportions, required flood warnings for the benefit of lumber, livestock, and agricultural interests. Stock and portable property were taken from the bottoms and there were no losses of consequence.

From August 17 to 19 the average rainfall over the upper drainage basin of the Wisconsin River was very nearly 5 inches, and under ordinary conditions there might have been a repetition of the great flood of July 24–25, 1912. That a disastrous flood did not occur was due (1) to the very dry condition of the soil and (2) to the prompt collection and dissemination of data and information by the Weather Bureau and its immediate and effective use by the power companies. These companies were enabled to open sluice gates in time to permit great volumes of water to pass down the stream in advance of the flood waters and materially lower the flood crest. Only at Knowlton, Wis., did the waters rise much above the flood stage (crest, 18.7 feet, or 6.7 feet above flood stage), and the reason therefor lies in the heavier local rains (over 6 inches) that fell over that section (Wausau 7.86 and Knowlton 5.42 inches). Flood stages did not actually occur below Wisconsin Rapids, yet the district officials wisely issued warnings for moderate floods, and a special report received indicated that the warnings permitted the saving of a large quantity of construction equipment at Prairie du Sac, Wis.

The losses as reported did not exceed $6,000 in crops and $1,000 in lost lumber. There was, however, some damage to railroad trackage in the Wisconsin Valley.

Flood stages during the month of August, 1926

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE					
Santee:	*Feet*			*Feet*	
Rimini, S. C.	12	(1)	6	13.2	3
Ferguson, S. C.	12	3	8	12.6	7
MISSISSIPPI DRAINAGE					
Hocking: Athens, Ohio	17	19	19	17.7	19
Little Miami: Kings Mills, Ohio	17	19	19	19.9	19
Tippecanoe: Norway, Ind.	6	22	24	6.1	22
Wisconsin:					
Knowlton, Wis.	12	21	23	18.7	22
Wisconsin Rapids, Wis.	12	23	23	12.6	23
Black: Black Rock, Ark.	14	19	19	14.1	19
Sulphur:					
Ringo Crossing, Tex.	20	19	21	21.3	20
Finley, Tex.	24	(1)	3	25.1	1
WEST GULF DRAINAGE					
Trinity:					
Dallas, Tex.	25	(1)	1	30.3	1
		20	21	26.0	21
Trinidad, Tex.	28	2	6	31.1	5

[1] Continued from last month.

MEAN LAKE LEVELS DURING AUGUST, 1926

By UNITED STATES LAKE SURVEY

[Detroit, Mich., Sept. 3, 1926]

The following data are reported in the Notice to Mariners of the above date:

Data	Lakes [1]			
	Superior	Michigan and Huron	Erie	Ontario
Mean level during August, 1926:	*Feet*	*Feet*	*Feet*	*Feet*
Above mean sea level at New York	600.98	578.59	571.30	244.99
Above or below—				
Mean stage of July, 1926	+0.12	+0.06	+0.08	−0.21
Mean stage of August, 1925	−0.54	+0.15	+0.22	+0.09
Average stage for August, last 10 years	−1.47	−1.06	−1.16	−1.30
Highest recorded August, stage	−2.95	−4.02	−2.81	−3.27
Lowest recorded August, stage	−0.54	+0.15	+0.22	+0.64
Average departure (since 1860) of the August level from the July level	+0.11	−0.06	−0.19	−0.31

[1] Lake St. Clair's level: In August, 1926, 574.01 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, AUGUST, 1926

By J. B. KINCER

General summary.—East of the Mississippi River the widespread rainfall about the beginning of the month was very favorable in conditioning the soil for crop growth and for plowing, and there was sufficient moisture in practically all sections of this area, except the middle Appalachian Mountain region. In the extreme lower Missouri Valley and over much of the central and northern plains, however, very unfavorable droughty conditions continued until after the middle of the month when there was sufficient rain to be of much benefit, especially to the range and to cultivated crops that were not too far gone. During the latter part of the month rainfall continued insufficient over the Great Basin, but the drought was largely relieved in the Great Plains and some good showers occurred over the far Northwest.

Near the close of the month heavy rains and high winds attending the tropical storm which moved inland over central Gulf districts were damaging to growing crops, and at the same time too much rain in the Southeast was unfavorable. Otherwise weather conditions during this period were mostly favorable, except for interruption to field work, especially to haying and threshing, in most of the interior valley and northern States.

Small grains.—Early in the month the harvesting of spring wheat was completed over southern portions of the belt, and oat harvest was nearly finished, except in some late northern districts. During the first three weeks, however, too much rain over most of the Winter Wheat Belt and to the northward was decidedly unfavorable for threshing, especially from Pennsylvania, the northern portions of the Ohio Valley States, Iowa, and South Dakota northward, and there was considerable damage to grain in shock by sprouting and molding. Toward the close of the month conditions became more favorable, with moderately warm and mostly fair weather, and threshing made better progress. The rains were favorable in conditioning the soil for plowing, and this work became active with soil in good condition everywhere, except in some of the more western sections of the Winter Wheat Belt. Grain sorghums made mostly satisfactory advance in the lower Great Plains, as did also rice in Arkansas, Louisiana, Texas, and California, except for damage in Louisiana by the tropical storm.

Corn.—From the lower Missouri and middle Mississippi Valleys eastward rains during the first half of the month favorably affected the corn crop, and progress was very good to excellent. In the extreme lower Ohio Valley where severe drought had prevailed corn responded nicely to the better weather conditions, and additional moisture was opportune in much of the lower Missouri Valley. In parts of the central Great Plains, however, especially in western Kansas and southern Nebraska, the crop was badly damaged by the drought, and the rains that occurred soon after the middle of the month came too late to be of much benefit. The latter part was generally favorable east of the Great Plains, but the corn crop was mostly late; dry, warm weather was needed to hasten maturity. Late corn advanced favorably in the South, with the crop showing material improvement in the Southeastern States where moisture conditions were improved.

Cotton.—The early part of the month was fairly favorable for cotton, although there was too much moisture in parts of the East, with complaints of weedy growth and of shedding in wet areas. During the middle portion conditions were less favorable, as rainfall was too frequent in much of the East and also in the north-central portion of the belt. In the western portion the progress of the crop was poor to only fair, principally because of shedding and weevil and worm damage. During the latter part of the month temperatures were mostly favorable and rainfall unevenly distributed, with heavy to excessive amounts in Gulf sections from the Mississippi Valley eastward to Florida, which were unfavorable. There was considerable damage in south-central portions of the belt from wind and rains accompanying the tropical storm.

Miscellaneous crops.—The frequent rains and moderate temperatures were unusually favorable for meadows and pasture lands in practically all sections from the Mississippi Valley eastward, and they were in generally good to excellent condition for the season. In the central and northern plains, however, it was too dry for the range, with unfavorable drought continuing in the Great Basin. There was some complaint of potatoes rotting, because of too much moisture, in some Central and Northern States east of the Great Plains, but in general truck crops showed improvement in the eastern half of the country. Prunes were damaged considerably by rain in the Pacific Northwest, but good fruit-drying weather prevailed in California.

CLIMATOLOGICAL TABLES *

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation, by sections, August, 1926

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	80.6	+1.0	3 stations	101	[1] 20	Valley Head	59	8	6.90	+2.36	Robertsdale	14.15	Fort Deposit	2.50
Arizona	80.1	+0.4	Fort Mohave	118	9	2 stations	30	[1] 24	1.09	−1.22	Elgin (near)	4.78	5 stations	0.00
Arkansas	80.7	+1.0	Calico Rock	110	6	Dutton	47	[1] 25	5.50	+1.81	Mammoth Spring	12.91	Grannis	1.08
California	72.1	+0.4	Greenland Ranch	124	24	Helm Creek	24	27	0.08	−0.01	Julian	1.52	98 stations	0.00
Colorado	65.8	+1.1	2 stations	105	[1] 4	Hermit	24	[1] 18	1.41	−0.63	Julesburg	5.68	Rocky Ford	0.00
Florida	81.9	+0.5	2 stations	99	[1] 22	Cottage Hill	66	4	8.13	+1.41	Vernon	16.13	Fernandina	1.28
Georgia	81.0	+1.6	Eastman	102	31	Clayton	50	26	5.05	−0.17	Canton	10.76	Lumber City	1.38
Idaho	66.6	+0.8	Murphy	112	24	Grays Lake	22	31	1.34	+0.66	Musselshell	5.27	Gooding	T.
Illinois	75.7	+1.5	Mascoutah	105	6	Waukegan	48	28	4.78	+1.33	Cairo	12.02	Joliet	0.97
Indiana	75.4	+2.1	Vincennes	103	11	3 stations	48	[1] 8	6.16	+2.85	Greenfield	12.97	Whiting	0.79
Iowa	73.5	+1.8	Lenox	103	9	2 stations	47	7	3.80	+0.36	Fairport	7.33	Audubon	1.64
Kansas	79.4	+1.9	2 stations	112	9	Plains	48	27	2.84	−0.22	Pleasanton	11.81	Tribune	0.29
Kentucky	77.3	+1.7	Glasgow	101	6	Middlesboro	51	26	7.51	+3.80	Princeton	12.63	Sergent	2.26
Louisiana	82.4	+0.8	Dodson	107	22	Lake Providence	58	9	8.09	+2.86	Donaldsonville	17.93	Plain Dealing	1.34
Maryland-Delaware	75.0	+1.7	Frederick, Md	104	11	Grantsville, Md	42	31	6.42	+2.15	Oakland, Md	10.13	Wilmington, Del	2.67
Michigan	67.8	+1.3	Midland	97	28	Vanderbilt	28	31	3.43	+0.63	Detroit	8.33	Seney	0.75
Minnesota	66.9	+0.3	New Ulm	102	27	Ada	35	7	3.63	+0.48	Willmar	9.76	Gonvick	0.98
Mississippi	81.8	+1.3	4 stations	103	[1] 6	Duck Hill	59	8	6.42	+2.20	Bay St. Louis	16.42	Vicksburg	1.89
Missouri	77.5	+1.5	6 stations	106	[1] 6	3 stations	50	[1] 25	5.63	+1.95	Hollister	13.55	St. Louis (No. 1)	1.83
Montana	64.3	−0.3	Springbrook	110	26	Adel	25	27	1.60	+0.46	Wheaton	4.09	Choteau	0.36
Nebraska	74.8	+2.0	2 stations	111	[1] 25	Fort Robinson	39	21	3.68	+0.87	Orleans	9.96	Lake Minatare	0.19
Nevada	71.6	+0.4	Logandale	112	23	Rye Patch	22	31	0.24	−0.18	Sharp	2.76	9 stations	0.00
New England	66.5	−0.3	Waterbury, Conn	100	3	2 stations	32	[1] 19	3.63	−0.23	Millinocket, Me	7.68	Concord, N. H	1.18
New Jersey	72.8	+0.8	Bridgeton	101	[1] 13	Runyon	38	31	6.58	+1.76	Hightstown	8.84	Bridgeton	3.74
New Mexico	70.5	+0.4	Nara Visa	108	[1] 3	Senorito (near)	28	18	1.56	−0.88	Glenrio	4.52	Tularosa	0.17
New York	68.3	+1.0	West Point	99	3	Allegany State Park	32	31	4.91	+1.14	Mount Vernon	9.30	Cairo	2.43
North Carolina	78.2	+2.8	Weldon	106	13	Parker	40	8	4.24	−1.09	Andrews	9.87	Manteo	1.10
North Dakota	65.6	+0.2	Beach	105	26	3 stations	36	[1] 15	2.43	+0.15	Ellendale	9.76	Cooperstown	0.80
Ohio	74.0	+2.3	2 stations	101	11	Canfield	38	31	5.92	+2.45	Hamilton (No. 2)	11.38	Wooster (No. 1)	2.75
Oklahoma	80.9	+0.1	Mangum	111	7	2 stations	50	26	4.04	+0.68	Antlers	9.42	Kenton	0.40
Oregon	67.1	+0.5	Brockman Ranch	111	24	Fremont	25	27	1.48	+0.94	Classic Lake	4.69	2 stations	0.00
Pennsylvania	71.9	+1.9	Somerset	103	10	West Bingham	32	31	5.69	+1.46	Muncy Valley	10.04	2 stations	2.95
South Carolina	80.7	+1.8	2 stations	100	20	Hogback Mountain	55	24	3.46	−2.36	Edgefield	6.05	Little Mountain	1.51
South Dakota	71.2	+1.4	5 stations	110	[1] 25	Camp Crook	40	23	2.51	−0.12	Milbank	5.97	Vivian	0.60
Tennessee	78.1	+1.3	Perryville	101	12	Crossville	48	26	7.91	+3.98	Franklin	13.83	Parksville	3.93
Texas	82.6	−0.1	Encinal	112	1	Junction	48	26	2.33	−0.23	Rockland	8.95	Rio Medina	0.00
Utah	70.3	+0.9	St. George	110	24	2 stations	26	31	1.06	+0.04	Silver Lake	2.94	Leeds (near)	0.00
Virginia	76.5	+2.4	Winchester	106	11	Burkes Garden	44	[1] 9	5.68	+1.27	Onley	14.46	Callaville	1.62
Washington	65.6	−0.4	Mottinger	107	25	2 stations	32	[1] 20	1.87	+0.93	Paradise Inn	7.01	Wahluke	0.05
West Virginia	74.0	+2.1	Romney	105	11	Bayard	38	31	6.94	+3.00	Bayard	15.36	Upper Tract	2.95
Wisconsin	67.2	+0.4	Port Washington	101	28	Long Lake	36	[1] 17	4.35	+1.03	Wausau	8.76	Port Washington	0.54
Wyoming	64.2	+0.4	Colony	105	26	2 stations	24	[1] 5	1.53	+0.40	Dull Center (near)	3.64	2 stations	0.09
Hawaii	75.2	+0.6	2 stations	94	[1] 21	Kula Sanitarium	51	30	7.49	+0.72	Pilbonua	41.94	4 stations	0.00

LATE REPORTS

Alaska (July)	55.9	+1.0	3 stations	85	[1] 12	Barrow	26	3	4.09	+0.62	Latouche	14.09	Barrow	0.05
Montana (July)	69.1	+2.8	Glendive	108	31	Conway's Ranch	26	21	1.16	−0.27	Mystic Lake	4.03	Ingomar	0.14
Hawaii														
Porto Rico (August)	79.0	−0.1	Canovanas	99	4	Aibonito	52	4	7.40	+0.21	Maricao	18.40	Lajas Finca Julia	1.58

* For description of tables and charts, see REVIEW, January, 1926, p. 32.
[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1926*

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
New England							67.2	−0.2										81	3.47	−0.4										6.2		
Eastport	76	67	85	29.91	29.99	+.03	59.0	−1.7	84	4	67	47	21	51	33	56	55	87	1.92	−1.3	12	5,605	s.	30	w.	31	7	10	14	6.3	0.0	0.0
Greenville, Me	1,070	6	....	28.85	30.00	....	62.6	....	85	3	73	37	21	52	38	....	....	....	2.72	....	13	4,510	se.	20	....	30	6	13	12	....	0.0	0.0
Portland, Me	103	82	117	29.90	30.02	+.04	64.9	−1.5	88	4	72	48	22	58	25	60	56	78	1.87	−1.7	10	4,916	s	31	nw.	30	10	11	10	5.8	0.0	0.0
Concord	289	70	79	29.70	30.00	+.02	67.0	+0.2	89	3	77	41	21	57	30	....	....	....	1.15	−2.6	10	3,293	se.	21	w.	30	12	9	10	5.3	0.0	0.0
Burlington	403	11	48	29.56	29.99	+.02	66.0	−1.9	84	6	74	46	20	58	26	....	....	....	3.98	0.0	12	6,309	s.	34	s.	23	2	8	21	7.8	0.0	0.0
Northfield	876	12	60	29.09	30.02	+.04	62.8	−0.6	83	11	74	38	20	52	33	59	57	84	5.22	+1.3	12	4,509	s.	22	nw.	30	0	14	17	7.7	0.0	0.0
Boston	125	115	188	29.87	30.00	+.01	70.4	+0.5	94	3	78	55	19	63	25	63	59	72	3.91	−0.1	10	5,597	e.	26	sw.	30	6	13	12	6.4	0.0	0.0
Nantucket	12	14	90	29.99	30.00	+.01	67.6	−0.2	87	4	74	54	22	62	19	64	62	88	2.56	−0.5	10	9,205	sw.	36	se.	17	8	10	13	6.2	0.0	0.0
Block Island	26	11	46	29.97	30.00	+.01	68.9	+0.4	84	4	73	59	19	64	14	64	62	84	4.02	+0.5	9	10,314	sw.	36	nw.	12	13	8	10	5.1	0.0	0.0
Providence	160	215	251	29.84	30.01	+.02	70.4	−0.6	95	3	79	52	23	62	25	64	60	75	4.20	+0.2	12	6,758	nw.	35	nw.	30	7	10	14	5.9	0.0	0.0
Hartford	159	122	....	29.84	30.01	+.02	71.2	+2.3	94	3	80	51	21	63	23	....	....	....	3.88	−0.7	11	....	sw.	....	....	....	12	4	15	5.6	0.0	0.0
New Haven	106	74	153	29.90	30.00	+.01	71.3	+1.0	94	3	79	54	21	64	24	66	63	79	5.48	+0.5	12	5,288	ne.	23	nw.	12	10	8	13	5.8	0.0	0.0
Middle Atlantic States							74.6	+1.3										79	5.75	+1.2										5.9		
Albany	97	102	115	29.90	30.00	+.02	71.0	+0.2	90	4	79	52	19	63	25	64	61	76	3.89	−0.1	13	5,067	s.	25	ne.	2	6	14	11	6.1	0.0	0.0
Binghamton	871	10	84	29.09	30.01	+.02	69.6	+1.6	92	3	78	47	31	61	30	....	....	....	3.73	+0.4	13	3,293	w.	24	nw.	2	7	7	17	6.9	0.0	0.0
New York	314	414	454	29.68	30.01	+.01	72.8	−0.3	92	3	79	58	22	66	21	66	63	77	7.57	+3.0	16	9,358	e.	44	nw.	14	3	13	15	6.9	0.0	0.0
Harrisburg	374	94	104	29.62	30.01	.00	73.8	+1.2	98	11	81	57	22	66	26	67	64	78	4.99	+0.7	17	3,701	nw.	26	n.	12	7	8	16	6.6	0.0	0.0
Philadelphia	114	123	190	29.89	30.01	+.01	75.4	+0.6	96	3	83	59	21	68	24	69	66	78	5.99	+1.4	14	4,851	sw.	23	n.	14	7	10	14	6.3	0.0	0.0
Reading	325	81	98	29.66	30.00	....	73.8	....	96	11	82	56	31	66	28	68	65	80	7.05	+2.6	13	3,233	e.	24	e.	12	13	6	12	5.7	0.0	0.0
Scranton	805	111	119	29.17	30.02	+.02	70.6	+0.8	91	3	79	53	31	63	29	64	61	76	6.60	+2.4	15	3,756	ne.	20	w.	29	4	7	20	7.6	0.0	0.0
Atlantic City	52	37	172	29.94	30.00	.00	74.2	+1.7	91	29	79	60	31	69	22	69	67	80	6.96	+2.7	11	11,476	s.	48	nw.	14	12	7	12	5.3	0.0	0.0
Cape May	17	13	49	....	....	....	75.5	+2.1	94	3	82	58	31	69	23	....	....	....	8.82	+4.6	14	....	e.	....	....	....	....	....	....	....	0.0	0.0
Sandy Hook	22	10	55	29.98	30.00	....	73.2	....	93	3	78	62	31	68	20	67	65	81	6.46	....	17	9,160	e.	45	n.	12	7	13	11	6.1	0.0	0.0
Trenton	190	159	183	29.80	30.00	....	73.5	....	94	11	81	57	31	66	24	67	65	80	7.73	+2.4	15	6,064	e.	36	nw.	29	8	11	12	6.1	0.0	0.0
Baltimore	123	100	215	29.87	29.99	−.02	76.8	+1.3	98	14	84	59	21	69	25	70	67	76	5.58	+1.4	13	6,500	ne.	40	nw.	14	13	6	12	5.7	0.0	0.0
Washington	112	62	85	29.88	30.00	−.01	76.4	+1.4	99	12	85	60	22	68	29	70	68	81	5.50	+1.1	15	3,760	nw.	42	nw.	16	9	10	12	5.8	0.0	0.0
Cape Henry	18	8	54	29.97	29.99	....	79.6	....	101	14	88	63	27	72	27	73	71	80	5.44	−0.7	14	8,346	sw.	68	ne.	22	9	14	8	5.0	0.0	0.0
Lynchburg	681	153	188	29.29	30.01	−.01	77.8	+2.2	100	11	87	59	21	68	28	69	66	74	1.67	−2.6	14	4,475	w.	34	ne.	5	10	15	6	4.8	0.0	0.0
Norfolk	91	170	205	29.91	30.01	+.01	79.6	+2.2	98	14	88	65	24	71	25	72	69	77	5.73	−0.2	14	8,377	sw.	54	ne.	22	9	15	7	5.2	0.0	0.0
Richmond	144	11	52	29.86	30.00	−.01	78.0	+1.5	100	14	87	62	27	69	27	71	69	80	5.24	+0.8	13	4,919	sw.	37	w.	17	13	10	8	4.6	0.0	0.0
Wytheville	2,304	49	55	27.72	30.01	.00	72.4	+1.9	92	11	82	55	9	63	30	67	65	84	5.26	+0.7	17	3,363	w.	26	sw.	16	9	10	12	5.6	0.0	0.0
South Atlantic States							80.8	+2.7										81	3.98	−2.2										4.8		
Asheville	2,253	70	84	27.76	30.04	+.02	74.2	+3.7	87	11	83	59	27	65	28	67	66	86	4.00	−0.6	15	3,972	se.	28	n.	11	4	20	7	5.7	0.0	0.0
Charlotte	779	55	62	29.22	30.03	+.01	80.7	+3.6	97	13	90	65	21	71	24	71	69	76	5.52	0.0	8	2,400	sw.	26	ne.	20	4	19	8	5.5	0.0	0.0
Hatteras	11	11	50	30.00	30.01	+.01	79.6	+1.6	90	5	85	67	29	74	21	75	73	82	2.34	−3.5	5	8,439	sw.	31	w.	25	17	10	4	3.5	0.0	0.0
Raleigh	376	103	110	29.63	30.01	.00	80.0	+3.0	95	13	89	64	25	71	25	72	69	77	5.02	−0.9	7	5,243	sw.	31	se.	5	11	14	6	5.0	0.0	0.0
Wilmington	78	81	91	29.96	30.04	+.04	81.5	+3.9	94	5	90	67	27	73	22	76	73	83	8.94	+2.4	11	4,934	sw.	23	sw.	25	14	15	2	4.1	0.0	0.0
Charleston	48	11	92	30.00	30.05	+.04	83.3	+2.3	97	31	90	72	21	77	19	77	75	82	2.38	−4.6	7	5,932	sw.	33	nw.	20	12	14	5	4.8	0.0	0.0
Columbia, S. C	351	41	57	29.66	30.03	+.02	82.4	+2.8	99	20	92	68	20	73	31	74	71	77	2.68	−4.1	7	4,387	sw.	28	sw.	1	6	22	3	4.5	0.0	0.0
Due West	711	10	55	29.31	30.07	....	80.2	....	94	20	90	68	26	71	23	....	....	....	3.47	....	11	4,986	sw.	38	nw.	20	8	20	3	5.0	0.0	0.0
Greenville, S. C	1,039	139	146	28.96	30.03	....	79.2	+3.4	92	10	88	66	26	70	24	71	69	79	4.06	....	11	5,297	sw.	54	w.	20	9	19	3	4.8	0.0	0.0
Augusta	182	62	77	29.84	30.03	+.02	82.8	+2.4	98	20	92	72	24	73	26	76	74	81	1.62	−4.0	7	2,780	s.	27	s.	1	8	21	2	4.7	0.0	0.0
Savannah	65	150	194	29.98	30.05	+.04	82.8	+2.1	95	31	91	71	19	75	23	76	75	86	4.07	−3.4	11	6,186	sw.	36	w.	25	14	14	3	4.3	0.0	0.0
Jacksonville	43	209	245	30.01	30.06	+.05	82.2	+0.5	94	31	89	71	20	75	20	76	74	83	3.18	−3.0	18	6,235	sw.	42	sw.	15	6	17	8	5.8	0.0	0.0
Florida Peninsula							82.7	+0.4										79	10.93	+4.4										5.8		
Key West	22	10	64	29.99	30.01	+.03	83.0	−0.5	92	8	89	71	12	77	17	77	75	78	15.83	+11.1	22	7,072	e.	37	w.	18	9	16	6	5.3	0.0	0.0
Miami	28	71	79	30.02	30.05	....	82.4	+0.4	92	4	88	72	11	77	16	76	74	78	9.69	+3.3	19	4,295	se.	33	se.	11	6	13	12	6.2	0.0	0.0
Tampa	35	70	87	30.01	30.04	+.04	82.8	+1.3	94	9	91	69	31	75	23	76	74	81	7.26	−1.3	16	3,782	e.	30	ne.	31	3	24	4	5.5	0.0	0.0
Titusville	44	5	....	30.00	30.05	....	83.0	....	98	23	92	70	1	74	24	....	....	....	3.82	....	6	....	se.	....	....	....	6	10	9	5.0	0.0	0.0
East Gulf States							81.2	+1.3										81	6.45	+1.6										5.7		
Atlanta	1,173	190	216	28.84	30.05	+.04	79.0	+2.0	91	30	88	67	21	70	22	72	70	79	7.75	+3.3	14	5,144	s.	40	nw.	21	5	12	14	6.2	0.0	0.0
Macon	370	78	87	29.65	30.04	+.03	81.6	+1.7	96	31	91	70	27	72	24	74	72	78	3.79	−0.4	9	3,417	s.	30	sw.	31	10	16	5	4.7	0.0	0.0
Thomasville	273	49	58	29.75	30.04	+.04	81.4	+0.4	95	22	90	70	17	72	23	74	73	83	6.59	+1.6	17	2,072	e.	20	n.	31	4	20	7	6.4	0.0	0.0
Apalachicola	36	42	49	29.99	30.03	....	81.8	....	92	5	88	73	6	76	17	76	75	82	5.77	....	15	4,692	s.	39	ne.	22	10	13	8	4.8	0.0	0.0
Pensacola	56	149	185	29.96	30.02	+.04	81.0	+0.1	91	22	86	71	14	76	16	76	74	82	15.24	+8.1	15	7,742	s.	45	s.	26	6	14	11	6.1	0.0	0.0
Anniston	741	9	57	29.28	30.05	+.06	79.5	+3.1	94	7	90	64	8	69	28	....	....	....	5.40	+0.9	17	2,341	s.	24	n.	21	12	13	6	4.5	0.0	0.0
Birmingham	700	11	48	29.29	30.04	+.06	80.3	+1.1	96	21	89	65	8	71	24	73	71	82	3.51	−1.0	15	3,665	s.	27	s.	2	6	16	9	5.6	0.0	0.0
Mobile	57	125	161	29.95	30.01	+.03	82.0	+1.0	96	7	89	70	25	75	24	76	75	84	9.01	+2.2	18	6,042	s.	43	e.	25	5	17	9	5.9	0.0	0.0
Montgomery	223	100	112	29.79	30.03	+.04	81.8	+1.0	96	21	90	71	16	74	22	75	73	82	5.73	+1.5	14	3,506	sw.	31	sw.	16	2	21	8	6.2	0.0	0.0
Corinth	469	6	....	....	....	....	81.1	....	97	10	91	63	26	72	27	....	....	....	7.22	....	19	....	s.	....	....	....	3	24	4	....	0.0	0.0
Meridian	375	87	95	29.62	30.00	+.02	80.6	+1.1	95	21	89	68	8	72	24	74	73	82	4.78	+1.2	15	3,415	sw.	25	n.	22	6	17	8	5.7	0.0	0.0
Vicksburg	247	65	73	29.73	30.00	+.02	81.8	+1.0	96	6	90	67	8	74	23	74	72	78	1.89	−1.6	11	4,389	s.	30	ne.	26	5	16	10	6.0	0.0	0.0
New Orleans	53	76	84	29.94	29.99	+.01	83.6	+1.4	95	20	90	72	25	77	19	77	75	80	7.25	+1.6	20	4,172	sw.	44	se.	25	0	16	15	6.8	0.0	0.0
West Gulf States							82.7	+0.9										73	2.13	−0.9										4.3		
Shreveport	249	77	93	29.71	29.97	....	83.5	+1.5	98	23	92	68	26	75	22	75	72	76	2.21	0.0	6	4,789	s.	29	ne.	26	12	17	2	4.1	0.0	0.0
Bentonville	1,303	11	44	....	....	....	77.1	+0.6	100	6	88	55	25	66	32	....	....	....	7.47	....	13	2,672	s.	22	se.	21	16	9	6	....	0.0	0.0
Fort Smith	457	79	94	29.48	29.95	−.02	82.6	+2.1	102	6	93	62	26	72	26	72	69	70	2.70	−1.0	9	4,568	e.	38	sw.	23	18	7	6	3.8	0.0	0.0
Little Rock	357	136	144	29.60	29.97	−.01	81.2	+1.4	103	6	90	65	25	72	27	73	69	74	3.99	+0.3	9	4,953	s.	40	w.	18	10	11	10	5.3	0.0	0.0
Brownsville	57	53	61	29.86	29.92	....	84.5	+0.6	97	24	92	73	26	77	23	76	74	79	1.84	....	5	5,341	s.	23	s.	17	18	12	1	3.3	0.0	0.0
Corpus Christi	20	11	73	29.93	29.95	+.02	84.4	+1.9	96	24	90	72	27	78	21	77	75	78	0.93	−1.4	6	8,206	se.	31	se.	17	13	12	6	4.5	0.0	0.0
Dallas	512	109	117	29.42	29.96	....	83.2	....	101	6	93	60	26	73	26	....	....	....	3.63	....	8	5,471	s.	27	nw.	23	22	6	3	3.0	0.0	0.0
Fort Worth	670	106	114	29.24	29.94	.00	83.1	+0.1	103	3	94	60	26	72	30	71	66	64	4.39	+1.7	6	6,877	s.	31	s.	21	14	14	3	4.1	0.0	0.0
Galveston	54	106	114	29.93	29.99	+.03	83.7	+0.7	97	7	88	68	27	79	18	77	74	77	0.92	−4.1	8	7,552	s.	30	n.	25	15	12	4	4.2	0.0	0.0
Groesbeck	461	11	56	29.49	29.96	....	82.9	....	98	21	94	63	26	72	26	....	....	....	0.38	....	5	6,908	s.	40	s.	21	11	18	2	4.2	0.0	0.0
Houston	138	292	314	29.83	29.97	....	82.7	−0.2	96	6	90	65	26	75	21	....	....	....	6.87	....	13	7,734	s.	34	se.	31	11	14	6	4.7	0.0	0.0
Palestine	510	64	72	29.45	29.96	−0.1	82.2	+0.4	98	7	92	66	28	73	23	73	70	74	1.29	−0.9	5	4,975	s.	28	se.	10	7	19	5	5.2	0.0	0.0
Port Arthur	34	58	66	29.93	29.97	....	83.4	....	97	6	90	68	26	77	23	....	....	....	6.66	....	11	5,794	s.	37	ne.	7	13	10	8	4.8	0.0	0.0
San Antonio	693	119	132	29.23	29.94	+.01	84.4	+0.9	100	9	95	64	27	74	26	73	68	66	0.31	−2.4	3	5,355	se.	23	s.	3	8	17	6	5.1	0.0	0.0
Taylor	583	55	63	29.38	29.99	+.04	82.6	+0.9	100	7	93	62	27	72	29	....	....	....	2.47	0.0	6	5,621	s.	25	se.	21	13	14	4	4.3	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1926*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Travelling direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*° F.*	*° F.*	*°F.*		*°F.*	*°F.*		*°F.*	*° F.*	*°F.*	*°F.*	*%*	*In.*	*In.*		*Miles.*							*0–10*	*In.*	*In.*
							76.4	+1.4										79	5.90	+2.5										6.0		
Chattanooga	762	189	213	29.22	30.01	+.01	78.2	+0.7	93	6	87	63	26	70	25	71	68	80	4.80	+1.0	21	3,954	sw.	42	s.	11	4	15	12	6.2	0.0	0.0
Knoxville	905	102	111	28.98	30.01	.00	78.0	+1.3	94	12	87	59	23	69	27	70	68	80	5.20	+1.2	13	4,121	sw.	30	w.	20	5	18	8	5.6	0.0	0.0
Memphis	399	76	97	29.57	29.98	.00	80.6	+1.2	97	10	88	64	25	73	24	73	71	78	4.40	+1.2	11	4,634	sw.	37	n.	13	6	12	13	6.2	0.0	0.0
Nashville	546	168	191	29.45	30.03	+.03	78.4	+0.6	93	10	87	62	26	70	27	71	70	82	8.30	+4.8	17	4,742	s.	29	e.	10	7	12	12	6.3	0.0	0.0
Lexington	989	193	230	28.96	30.00	−.01	76.0	+1.5	95	11	84	60	8	68	25				7.03	+3.5	17	6,915	sw.	44	se.	11	14	11	6	4.0	0.0	0.0
Louisville	525	188	234	29.43	30.01	+.01	77.6	+0.6	94	11	86	60	26	70	23	71	68	79	6.89	+3.4	16	5,699	s.	52	nw.	6	6	16	9	5.7	0.0	0.0
Evansville	431	76	116	29.54	30.00	+.01	78.2	+0.8	94	11	86	60	8	70	24	71	69	78	6.44	+3.2	13	4,407	s.	23	nw.	31	4	21	6	6.1	0.0	0.0
Indianapolis	822	194	230	29.12	29.99	−.01	75.8	+2.1	93	11	84	57	8	68	25	68	66	77	4.97	+1.6	15	5,932	sw.	36	w.	6	6	10	15	6.3	0.0	0.0
Royal Center	736	11	55	29.20	29.98		73.4		93	5	83	49	8	64	32				3.53		9	5,040	sw.	27	nw.	20	8	9	14	5.7	0.0	0.0
Terre Haute	575	99	129	29.37	29.97		76.8		96	6	85	57	8	68	25	70	67	78	5.12		11	5,105	sw.	27	nw.	20	5	16	10	5.9	0.0	0.0
Cincinnati	627	11	51	29.34	30.00	−.01	75.6	+2.0	95	11	84	58	26	67	25	70	68	83	6.52	+3.2	14	3,557	sw.	34	nw.	6	4	13	14	6.4	0.0	0.0
Columbus	822	179	222	29.15	30.00	−.01	75.2	+2.2	96	11	83	59	31	67	25	68	65	77	6.13	+2.9	14	5,204	s.	38	sw.	12	7	8	16	6.5	0.0	0.0
Dayton	899	137	173	29.04	29.98		75.4	+2.0	92	11	84	59	25	67	25	68	66	77	6.59	+3.6	15	4,795	sw.	42	nw.	29	6	16	9	6.0	0.0	0.0
Elkins	1,947	59	67	29.04	30.02	.00	70.5	+1.4	93	11	80	51	9	61	34	65	63	86	6.57	+2.9	18	2,552	w	19	s.	1	5	13	13	6.8	0.0	0.0
Parkersburg	637	77	82	29.37	30.02	+.01	76.2	+2.3	93	11	85	58	26	68	30	69	66	77	5.75	+2.2	13	2,745	se.	24	s.	14	11	8	12	5.9	0.0	0.0
Pittsburgh	842	353	410	29.12	30.00	−.01	73.8	+0.9	94	11	82	52	31	66	28	66	62	73	2.95	−0.2	13	6,360	sw.	43	s.	1	6	11	14	6.5	0.0	0.0
Lower Lake Region							70.7	+1.0										76	5.01	+2.0										5.8		
Buffalo	767	247	280	29.17	29.99	.00	68.6	0.0	85	6	75	52	21	62	18	64	61	80	4.73	+1.7	15	10,317	sw.	64	sw.	6	4	15	12	5.3	0.0	0.0
Canton	448	10	61	29.51	29.98		68.2	−1.6	88	6	75	44	20	57	25				4.11	+1.4	10	5,381	sw.	31	sw.	7	7	17	7	5.7	0.0	0.0
Oswego	335	76	91		29.99	.00	67.8	−0.6	88	6	74	53	26	61	24			80	5.04	+2.4	13	6,042	s.	60	nw.	6	3	12	16		0.0	0.0
Rochester	523	86	102	29.44	30.00	+.01	69.9	+0.7	88	6	77	52	31	62	25	63	59	74	4.25	+1.3	16	5,290	sw	23	w.	28	6	10	15	6.7	0.0	0.0
Syracuse	397	97	113	29.37	30.01	+.02	68.1	−0.5	89	2	75	51	31	61	23				4.34	+1.0	15	4,545	s.	30	w.	30	7	7	17	6.8	0.0	0.0
Erie	714	130	166	29.23	29.98	−.03	71.5	+1.9	93	28	78	53	31	65	33	65	62	74	3.11	−0.2	13	9,217	w.	64	se.	20	6	17	8	5.0	0.0	0.0
Cleveland	762	199	201	29.13	29.99	−.02	72.2	+2.2	92	6	78	53	31	66	30	66	62	73	4.79	+1.6	13	7,557	s.	48	n.	5	7	10	14	6.2	0.0	0.0
Sandusky	629	62	70	29.32	29.99	−.02	74.0	+2.2	95	6	81	58	31	67	31				3.80	+0.4	14	5,157	sw.	33	sw.	12	6	15	10	5.8	0.0	0.0
Toledo	628	208	243	29.32	29.99	−.01	73.2	+1.9	91	28	81	58	31	65	26	66	64	76	7.64	+4.9	16	8,053	sw.	52	w.	21	13	13	5	4.6	0.0	0.0
Fort Wayne	856	113	124	29.07	29.98		73.9	+2.8	92	28	83	56	25	65	26	67	64	78	10.09		13	4,718	sw.	32	sw.	12	11	10	10	5.4	0.0	0.0
Detroit	730	218	258	29.22	30.00	−.01	72.0	+1.7	94	28	80	55	31	64	27	65	61	74	8.33	+5.6	11	6,847	sw.	33	sw.	20	6	13	12	6.0	0.0	0.0
Upper Lake Region							67.1	+0.6										79	2.76	−0.2										5.8		
Alpena	609	13	92	29.35	30.01	+.01	65.0	+0.9	93	28	73	44	31	57	28	60	57	78	2.39	−1.0	14	7,594	nw.	42	se.	21	8	10	13	6.1	0.0	0.0
Escanaba	612	54	60	29.35	30.01	+.02	64.1	−0.2	91	28	72	45	8	56	23	59	56	80	3.34	−0.3	7	6,521	n.	31	ne.	16	10	11	10	5.7	0.0	0.0
Grand Haven	632	54	89	29.30	29.97	−.02	68.6	+1.5	83	11	77	47	31	60	29	63	60	79	2.45	−0.1	7	6,141	n.	57	w.	23	9	11	11	5.4	0.0	0.0
Grand Rapids	707	70	87	29.24	29.99	−.01	71.2	+1.5	91	28	80	53	8	62	27	64	60	74	2.64	0.0	9	3,555	w.	26	nw.	23	5	11	15	6.6	0.0	0.0
Houghton	668	62	99	29.28	30.01	+.04	62.6	−1.1	85	27	71	44	8	54	32				4.02	+1.2	10	6,023	e.	36	sw.	6	4	10	17	7.3	0.0	0.0
Lansing	878	11	62	29.06	29.98		70.4	+1.9	96	23	81	50	30	60	33	64	62	81	2.61	0.0	7	3,094	ne.	18	w.	26	10	9	12	5.5	0.0	0.0
Ludington	637	60	66	29.30	29.99		66.0		81	15	74	45	31	58	30	61	58	80	3.79		7	5,920	n.	32	sw.	21	10	16	5	4.5	0.0	0.0
Marquette	734	77	111	29.22	30.02	+.04	62.7	−1.1	90	28	70	49	25	56	28	57	55	78	3.33	+0.5	9	5,608	w.	40	sw.	25	3	10	18	7.4	0.0	0.0
Port Huron	638	70	120	29.30	29.99	−.01	68.9	+1.1	93	28	76	48	31	62	25	63	61	79	5.49	+2.9	10	6,914	ne	37	se.	20	8	18	5	4.8	0.0	0.0
Saginaw	641			29.30	29.99		69.2	+0.5	95	28	80	49	31	59	33				5.34		10		sw.				7	6	18		0.0	0.0
Sault Sainte Marie	614	11	52	29.33	30.01	+.02	63.5	+1.4	83	28	72	42	31	54	30	57	54	79	0.97	−2.2	8	4,941	nw.	30	ne.	26	10	13	8	5.1	0.0	0.0
Chicago	673	7	131	29.28	30.00	.00	72.0	+0.4	94	28	78	56	8	66	25	67	64	81	0.99	−1.9	9	6,945	ne.	35	sw.	26	9	10	12	5.6	0.0	0.0
Green Bay	617	109	141	29.33	29.98	−.01	67.8	+0.1	91	28	76	50	18	60	24	62	59	78	3.36	+0.3	10	6,158	ne.	33	ne.	16	6	13	12	6.0	0.0	0.0
Milwaukee	681	125	139	29.26	29.99	−.01	69.6	+0.4	97	28	77	54	8	62	25	63	60	76	0.65	−2.2	5	6,172	n.	28	n.	1	7	15	9	5.5	0.0	0.0
Duluth	1,133	5	47	28.81	30.01	+.04	63.4	+0.8	90	2	71	49	24	56	32	58	56	84	3.61	+0.1	14	7,492	ne.	42	nw.	6	10	10	11	5.8	0.0	0.0
North Dakota							65.8	−0.4										67	1.47	−0.8										5.2		
Moorhead	940	50	58	28.96	29.97	+.01	66.6	+0.5	96	27	78	48	29	55	35	59	56	73	1.83	−1.3	8	4,704	s.	35	nw.	5	9	11	11	5.3	0.0	0.0
Bismarck	1,674	8	57	28.24	29.99	+.05	66.8	−0.5	100	1	78	43	29	55	41	58	52	65	1.34	−0.6	6	6,136	e.	38	nw.	5	12	12	7	4.8	0.0	0.0
Devils Lake	1,478	11	44	28.41	29.97	+.03	64.0	−1.1	100	1	76	42	29	52	39	56	51	70	1.90	−0.9	11	5,959	se.	29	w.	27	8	13	10	5.5	0.0	0.0
Ellendale	1,457	10	56	28.44	29.98		66.5		99	25	78	46	29	56	45				9.76		10	8,311	ne.	40	nw.	5	11	10	10	5.6	0.0	0.0
Grand Forks	833	12	67				65.4		94	1	78	42	7	53	39				1.63		9		nw.	30	w.	20	14	9	8		0.0	0.0
Williston	1,878	41	48	27.99	29.94	+.01	65.8	−0.3	98	26	78	40	16	53	39	55	48	61	0.80	−0.5	9	5,713	ne.	36	w.	27	13	10	8	4.8	0.0	0.0
Upper Mississippi Valley							74.0	+1.3										77	4.17	+0.9										5.5		
Minneapolis	918	102	208	28.99	29.96		69.8	−0.1	99	27	78	54	14	61	33				3.72	0.0	11	6,460	n.	54	n.	15	10	9	12	5.8	0.0	0.0
St. Paul	837	236	261	29.09	29.98	+.01	69.6	+0.2	96	27	78	54	14	61	33				4.27	+0.8	10	6,475	se.	52	nw.	15	8	12	11	5.0	0.0	0.0
La Crosse	714	11	48	29.22	29.97	−.01	70.0	0.0	93	28	80	52	25	61	29				3.05	−0.4	7	2,514	nw.	18	sw.	16	11	9	11	5.7	0.0	0.0
Madison	974	70	78	28.97	29.99	.00	70.6	+0.8	93	28	79	56	8	62	23	64	60	74	1.12	−2.1	8	5,075	se.	24	nw.	23	11	7	13	5.8	0.0	0.0
Wausau	1,247	4		28.66	30.01		66.7		90	28	75	50	25	58	29				8.76		8		n.				9	8	14	6.2	0.0	0.0
Charles City	1,015	10	49	28.93	29.98	+.01	71.1	+2.0	93	27	81	54	24	61	32	65	62	77	2.53	−0.9	10	3,494	se.	25	s.	18	11	14	6	4.3	0.0	0.0
Davenport	606	71	79	29.33	29.98	.00	74.6	+1.5	94	28	84	59	7	65	27	68	65	78	4.15	+0.5	13	3,984	e.	26	s.	9	9	11	11	5.5	0.0	0.0
Des Moines	861	84	97	29.07	29.96	.00	75.8	+2.7	96	27	86	58	24	66	31	68	64	75	2.96	−0.7	7	4,173	n.	24	w.	22	9	8	14	5.8	0.0	0.0
Dubuque	700	81	96	29.22	29.96	−.01	72.8	+1.1	92	28	82	55	25	64	28	66	63	75	1.85	−1.2	9	3,684	se.	18	nw.	6	10	11	10	5.3	0.0	0.0
Keokuk	614	64	78	29.32	29.98	.00	76.0	+1.0	93	28	85	58	25	67	28	69	67	77	3.39	+0.2	13	3,877	s.	28	se.	9	11	6	14	5.5	0.0	0.0
Cairo	358	87	93	29.60	29.97	+.03	78.4	+0.6	94	11	86	64	25	70	23	72	70	85	12.02	+9.1	15	4,124	s.	42	sw.	16	5	10	16	6.5	0.0	0.0
Peoria	609	11	45	29.34	30.00	+.01	74.4	+1.9	93	11	84	55	25	65	25	68	67	83	6.79	+3.9	14	2,774	ne.	31	w.	29	11	10	10	5.2	0.0	0.0
Springfield	636	10	91	29.31	29.97	−.02	76.7	+2.2	99	11	86	59	8	68	27	69	66	76	4.39	+1.6	10	4,150	w.	24	s.	13	11	8	12	5.4	0.0	0.0
Hannibal	534	74	109	29.40	29.96	−.02	76.8	+1.8	98	10	86	58	25	67	30				6.31	+2.9	10	4,501	sw.	26	sw.	19	8	12	11	5.5	0.0	0.0
St. Louis	568	265	303	29.37	29.97	−.02	79.4	+2.1	100	11	88	64	8	70	28	69	65	70	1.83	−0.8	9	6,770	sw.	38	sw.	20	10	14	7	4.7	0.0	0.0
Missouri Valley							76.0	+2.0										67	3.78	+0.4										4.1		
Columbia, Mo	784	11	84	29.15	29.96	−.01	76.2	+0.6	101	10	86	55	25	66	27				5.07	+2.0	12	3,742	n.	23	n.	13	10	12	9	4.8	0.0	0.0
Kansas City	963	161	181	28.95	29.95	−.02	79.0	+2.4	103	9	88	63	24	70	30	69	64	67	3.87	−0.9	9	5,855	s.	34	ne.	6	11	16	4	4.4	0.0	0.0
St. Joseph	967	11	49	28.94	29.95		78.4		106	9	89	60	24	68	30	69	65	72	4.60		7	4,276	se.	38	nw.	11	11	19	1	3.5	0.0	0.0
Springfield, Mo	1,324	98	104	28.60	29.97	.00	76.8	+1.1	98	6	86	58	25	68	27	69	65	74	6.63	+2.3	12	5,510	s.	35	nw.	20	18	9	4	3.4	0.0	0.0
Iola	984	11	50	28.94	29.95	−.01	78.8	+1.7	104	9	90	55	25	67	38				6.41	+2.8	11	3,364	s.	21	nw.	12	13	12	6	3.8	0.0	0.0
Topeka	987	92	107				77.1	+1.2	106	9	90	60	25	68	37				3.27	−1.0	10	5,431	se.	26	ne.	6	13	16	2	4.0	0.0	0.0
Lincoln	1,189	11	84	28.71	29.94	−.01	77.6	+3.2	105	26	89	57	24	66	34	66	61	65	4.43	+0.7	9	6,172	se.	34	n.	10	10	15	6	5.2	0.0	0.0
Omaha	1,105	115	122	28.80	29.96	.00	76.7	+2.3	101	27	87	60	24	67	31	67	62	67	2.65	−1.0	8	4,476	s.	40	nw.	22	17	8	6	3.9	0.0	0.0
Valentine	2,598	47	54	27.24	29.96	+.02	73.4	+1.7	104	25	87	54	6	60	46	61	55	62	3.05	+0.2	11	6,053	n.	36	nw.	17	17	10	4	3.6	0.0	0.0
Sioux City	1,135	94	164	28.78	29.96	+.01	74.4	+2.4	100	27	85	55	7	64	31	66	62	69	3.54	+0.5	11	7,037	s.	37	s.	22	12	15	4	4.3	0.0	0.0
Huron	1,306	59	74	28.60	29.98	+.03	71.4	+2.0	102	25	83	53	21	60	40	63	58	70	1.49	−1.2	8	6,070	s.	30	nw.	3	16	7	8	4.3	0.0	0.0
Pierre	1,572	70	75			.00	73.9	+1.1	107	25	87	54	21	61	50			60	0.78	−1.2	8	6,821	e.	37	ne.	3	14	9	8		0.0	0.0
Yankton	1,233	49	57	28.65	29.94	−.01	74.2	+2.2	99	27	85	54	7	63	35				4.11	+1.0	11	4,559	e.	24	s.	18	12	13	6	4.4	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1926*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles.*							*0–10*	*In.*	*In.*
Northern Slope							66.9	+0.5							56				1.77	+0.5										4.4		
Billings	3,140	5					68.3		104	25	85	42	6	52	54				1.02		7		nw.									
Havre	2,505	11	44	27.35	29.94	+.03	65.9	+0.5	100	24	80	41	22	52	51	54	45	57	2.41	+1.2	9	4,923	e.	38	w.	27	15	12	4	3.7	0.0	0.0
Helena	4,110	87	112	25.83	29.95	+.01	64.3	−0.7	95	24	77	45	21	52	41	51	41	51	0.87	+0.2	9	5,693	sw.	44	sw.	26	7	17	7	5.6	0.0	0.0
Kalispell	2,973	48	56	26.91	29.91	−.02	62.4	−0.4	98	24	76	39	21	49	48	50	40	53	2.23	+1.3	9	4,340	nw.	37	sw.	26	14	7	10	4.5	0.0	0.0
Miles City	2,371	48	55	27.48	29.98	+.05	70.6	−0.9	105	26	82	53	16	58	42	57	49	55	1.70	+0.7	7	4,293	e.	30	e.	12	16	8	7	3.9	0.0	0.0
Rapid City	3,259	50	58	26.64	29.99	+.09	69.7	+0.2	103	26	82	50	29	58	47	58	50	57	2.27	+0.2	10	4,913	n.	29	nw.	12	15	9	7	4.4	0.0	0.0
Cheyenne	6,088	84	101	24.12	29.95	+.03	67.0	+1.4	92	26	80	45	20	54	35	52	43	50	1.53	+0.1	9	7,529	w.	50	w.	22	9	16	6	4.9	0.0	0.0
Lander	5,372	60	68	24.72	29.96	+.04	67.2	+1.7	94	25	82	42	20	53	42	53	44	52	0.70	+0.2	9	3,838	sw.	46	sw.	27	12	14	5	4.4	0.0	0.0
Sheridan	3,790	10	47	26.13	29.97		67.0		102	26	82	43	20	52	49	55	47	52	0.74		11	3,304	nw.	29	sw.	27	15	12	4	4.1	0.0	0.0
Yellowstone Park	6,241	11	48	25.98	29.99	+.06	59.2	−1.7	85	25	74	36	20	45	38	48	41	62	1.37	+0.4	14	5,406	s.	47	s.	26	8	17	6	5.2	0.0	0.0
North Platte	2,821	11	51	27.10	29.96	+.02	75.6	+4.8	103	26	90	53	20	62	42	64	58	64	2.89	+0.4	9	4,206	s.	42	w.	10	20	8	3	3.0	0.0	0.0
Middle Slope							77.7	+1.8							58				1.42	−1.0										3.8		
Denver	5,292	106	113	24.82	29.96	+.04	73.0	+2.3	97	27	86	52	20	60	33	55	45	46	0.80	−0.5	7	5,284	s.	27	n.	12	12	17	2	3.9	0.0	0.0
Pueblo	4,685	80	86	25.36	29.94	+.03	74.2	+1.5	97	26	90	53	20	58	43	56	46	47	0.65	−0.9	10	4,588	nw.	40	nw.	5	16	13	2	3.9	0.0	0.0
Concordia	1,392	50	58	28.51	29.94	−.01	80.2	+3.7	108	8	93	58	24	68	36	66	59	58	1.42	−1.4	9	5,062	s.	30	nw.	19	13	15	3	4.2	0.0	0.0
Dodge City	2,509	11	51	27.42	29.96	+.03	78.2	+0.5	103	5	92	55	27	64	40	65	58	61	1.65	−0.9	7	6,082	se.	30	ne.	18	23	7	1	1.7	0.0	0.0
Wichita	1,358	139	158	28.54	29.93	−.02	79.8	+1.5	104	5	90	61	26	69	31	68	63	64	2.74	−0.4	12	7,730	s.	43	s.	21	16	11	4	3.6	0.0	0.0
Broken Arrow	765	11	56	29.15	29.97		80.4		104	5	92	59	25	69	31				2.77		9	7,012	s.	28	se.	12	14	11	6	4.2	0.0	0.0
Oklahoma City	1,214	10	47	28.69	29.94	.00	80.9	+1.2	101	8	91	60	25	70	30	70	67	70	1.23	−1.9	9	5,794	s.	24	n.	24	19	7	5	2.9	0.0	0.0
Southern Slope							80.4	+0.8							56				0.95	−1.4										3.1		
Abilene	1,738	10	52	28.17	29.92	.00	82.3	+0.3	103	18	94	54	26	70	35	68	61	58	1.42	−0.6	6	6,346	s.	32	s.	19	17	8	6	3.7	0.0	0.0
Amarillo	3,676	10	49	26.32	29.96	+.04	77.1	+1.4	100	2	90	57	28	64	34	63	56	60	1.76	−1.0	9	6,346	s.	38	s.	21	22	5	4	3.0	0.0	0.0
Del Rio	944	64	71	28.95	29.91	+.01	85.0	+0.8	99	18	95	62	26	75	31				0.23	−2.3	1	7,510	se.	37	nw.	24	17	13	1	3.3	0.0	0.0
Roswell	3,566	75	85	26.38	29.90	+.02	77.2	+0.6	97	20	91	55	26	63	38	61	52	50	0.40	−1.6	3	4,597	se.	32	e.	23	21	10	0	2.4	0.0	0.0
Southern Plateau							78.3	+0.9							48				0.82	−0.3										2.2		
El Paso	3,778	152	175	26.19	29.87	+.03	81.0	+1.8	98	10	93	61	26	69	32	62	50	41	0.27	−1.4	5	6,166	e.	37	ne.	12	21	10	0	2.8	0.0	0.0
Santa Fe	7,013	38	53	23.38	29.88	−.01	68.9	+1.5	89	27	82	48	24	56	35	54	46	50	1.50	−0.9	11	3,986	se.	37	ne.	23	16	12	3	3.7	0.0	0.0
Flagstaff	6,907	10	59	23.48	29.91	+.07	63.6	+0.8	85	23	80	38	22	48	44	51		58	1.29		6	5,316	nw.	29	se.	4	18	12	1		0.0	0.0
Phoenix	1,108	10	82	28.67	29.79	.00	88.9	+0.4	110	23	103	63	23	75	47	68	57	40	0.11	−0.8	3	3,729	e.	28	se.	5	25	6	0	1.5	0.0	0.0
Yuma	141	9	54	29.64	29.78	+.02	90.6	+0.2	112	24	105	67	31	77	40	73	65	51	2.19	+1.8	2	3,423	sw.	28	s.	2	26	4	1	1.4	0.0	0.0
Independence	3,957	5	25	25.92	29.87	+.06	76.6	+0.5	100	24	95	49	11	58	47	54			0.03	−0.1	2		nw.				21	8	2	1.6	0.0	0.0
Middle Plateau							72.2	+1.2							36				0.61	−0.2										2.6		
Reno	4,532	74	81	25.48	29.88	+.04	69.6	+2.6	97	24	87	36	31	52	44	49	32	30	T.	−0.3	0	5,967	w.	34	w.	2	28	2	1	1.1	0.0	0.0
Tonopah	6,090	12	20				71.0		90	1	82	44	31	60	27	52	35	32	0.01		1		se.								0.0	0.0
Winnemucca	4,344	18	56	25.62	29.92	+.04	70.0	+0.7	99	24	89	31	31	51	55	51	36	34	T.	−0.2	0	4,624	sw.	29	sw.	25	20	11	0	3.1	0.0	0.0
Modena	5,473	10	43	24.66	29.88	+.02	69.6	+0.4	95	24	86	42	31	54	45	52	39	41	0.76	−1.1	7	8,540	sw.	48	sw.	30	21	8	2	2.3	0.0	0.0
Salt Lake City	4,360	163	203	25.62	29.90	−.01	75.0	+0.5	98	1	86	49	31	63	33	57	44	39	1.22	+0.4	8	5,738	s.	47	nw.	10	19	7	5	3.2	0.0	0.0
Grand Junction	4,602	60	68	25.40	29.91	−.01	77.0	+1.6	99	1	91	56	31	63	34	57	43	37	1.06	0.0	10	4,552	se.	33	sw.	8	18	11	2	3.4	0.0	0.0
Northern Plateau							70.7	+0.8							41				1.29	+0.9										3.6		
Baker	3,471	48	53		29.93	−.02	65.8	+1.2	96	24	81	44	2	50	43				1.57	+1.2	6	3,922	nw.	24	sw.	26	15	12	4		0.0	0.0
Boise	2,739	78	86	27.11	29.90	−.03	73.0	+1.2	104	24	87	45	31	59	38	55	40	37	0.77	+0.6	5	3,603	nw.	26	nw.	30	21	6	4	3.0	0.0	0.0
Lewiston	757	40	48	29.10	29.89	−.06	73.6	+0.8	104	25	90	51	28	58	44				1.28	+0.9	6	2,376	e.	26	nw.	26	17	6	3	3.8	0.0	0.0
Pocatello	4,477	60	68	25.49	29.91	−.01	70.2	+0.6	99	25	84	46	31	57	40	53	41	43	0.80	+0.2	8	6,156	s.	42	s.	12	11	13	7	5.0	0.0	0.0
Spokane	1,929	101	110	27.91	29.92	−.03	68.0	−0.1	98	24	82	49	22	54	40	53	40	44	1.77	+1.2	5	3,987	s.	36	sw.	26	17	7	7	3.6	0.0	0.0
Walla Walla	901	57	65	28.86	29.91	−.05	73.6	+0.9	100	25	86	53	28	61	38	57	42	39	1.53	+1.1	6	3,642	s.	24	w.	26	21	6	4	2.6	0.0	0.0
North Pacific Coast Region							63.5	+1.3							76				1.94	+1.1										6.2		
North Head	211	11	56	29.82	30.04	+.01	58.7	+1.1	67	21	62	52	6	56	12	57	56	92	2.45	+1.9	12	8,559	n.	45	s.	17	3	6	22	8.3	0.0	0.0
Port Angeles	29	8	53		30.03		58.2		75	23	66	44	10	50	28				0.87	+0.2	8	4,481	nw.	33	w.	26	5	13	13		0.0	0.0
Seattle	125	215	250	29.86	29.99	−.01	64.1	+1.0	88	23	72	52	22	56	29	57	53	72	1.74	+1.1	7	5,282	s.	30	sw.	19	5	16	8	5.7	0.0	0.0
Tacoma	194	172	201	29.80	30.00	−.02	64.4	+1.8	87	23	73	52	21	56	31				2.05	+1.3	9	5,341	n.	31	sw.	26	7	13	11	6.0	0.0	0.0
Tatoosh Island	96	9	53	29.93	30.02	+.02	56.1	+0.8	66	22	59	50	10	53	13	55	55	95	2.83	+0.7	12	7,053	s.	34	e.	22	2	10	19	8.1	0.0	0.0
Yakima	1,071	5																														
Medford	1,425	4					70.4		101	24	89	48	10	52	48	58	51	64	0.52		4		nw.				20	8	3		0.0	0.0
Portland, Oreg	153	68	106	29.84	30.00	−.01	69.2	+2.5	91	22	80	54	1	54	34	61	57	70	1.95	+1.3	7	3,891	nw.	16	nw.	20	14	8	9	4.6	0.0	0.0
Roseburg	510	9	57	29.46	30.01	+.01	68.6	+0.6	97	24	84	47	3	54	43	58	51	61	1.68	+1.4	6	2,498	nw.	17	n.	1	13	9	9	4.2	0.0	0.0
Middle Pacific Coast Region							65.0	+0.2							66				0.24	+0.2										3.9		
Eureka	62	73	89	29.98	30.05	+.05	57.6	+1.6	68	23	62	49	3	54	15	55	54	90	0.54	+0.4	7	4,001	nw.	29	n.	31	6	9	16	7.1	0.0	0.0
Point Reyes	490	7	18	29.39	29.91		53.6	0−.9	64	23	57	46	6	50	11				0.06		2	17,642	nw.	60	nw.	30	3	6	22	7.8	0.0	0.0
Red Bluff	332	50	56	29.52	29.87	+.01	78.1	−1.6	106	1	94	50	30	62	41	60	47	41	0.60	+0.6	2	3,774	se.	25	nw.	31	28	3	0	0.9	0.0	0.0
Sacramento	69	106	117	29.81	29.88	+.03	73.0	+0.1	100	1	89	51	12	57	43	59	50	52	T.	0.0	0	6,382	s.	24	s.	29	29	2	0	0.7	0.0	0.0
San Francisco	155	208	243	29.78	29.95	+.03	60.8	+1.7	87	23	68	50	4	54	31	55	53	83	0.04	0.0	1	6,890	w.	34	w.	18	12	12	7	4.6	0.0	0.0
San Jose	141	12	110	29.80	29.95		67.0	+0.3	90	23	81	49	12	53	30				T.	0.0	0	4,634	nw.	24	nw.	30	25	5	1	2.1	0.0	0.0
South Pacific Coast Region							72.2	+0.8							64				0.01	0.0										2.2		
Fresno	327	89	98	29.52	29.86	+.04	80.4	−0.3	106	24	97	56	30	64	42	59	43	34	T.	0.0	0	5,963	nw.	29	nw.	29	29	2	0	0.7	0.0	0.0
Los Angeles	338	159	191	29.55	29.90	+.02	72.6	+1.5	102	25	82	60	23	63	32	64	60	72	T.	0.0	0	3,500	sw.	15	sw.	5	21	10	0	2.6	0.0	0.0
San Diego	87	62	70	29.81	29.90	+.01	69.3	+0.6	80	24	74	61	22	65	18	64	62	80	0.05	0.0	1	4,571	w.	17	s.	25	18	10	3	3.5	0.0	0.0
San Luis Obispo	201	32	40	29.74	29.96	+.02	66.4	+1.3	92	23	80	48	12	53	44	56	51	69	0.00	0.0	0	3,074	nw.	18	w.	30	26	5	0	2.0	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.90	29.98		80.6	+0.1	91	23	86	74	19	76	15				10.37	+3.0	22	8,477	e.	35	e.	15	8	18	5	5.1	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	29.74	29.86	+.02	80.0	−1.2	92	7	86	70	8	74	17	76	75	88	10.45	+2.4	21	4,190	nw.	26	n.	10	0	11	20	7.8	0.0	0.0
Colon	38	7	97	29.83	29.86	+.01	80.7	+0.5	91	6	86	71	8	75	16	76	76	88	20.84	+5.9	23	3,612	w.	22	n.	13	0	7	24	8.5	0.0	0.0
Alaska																																
Juneau	80	11	54				57.6		80	12	65	43	2	50	28	54	51	81	2.90		15	3,608	s.	28	nw.	10	9	7	15	6.5	0.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100				79.0		86	20	84	71	29	74	13	71	67	68	1.30	0.0	12	7,517	e.	34	e.	22	10	19	2	4.5	0.0	0.0

TABLE 2.—*Data furnished by the Canadian Meteorological Service, August, 1926*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+ mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches*	*Inches*	*Inches*
St. Johns, N. F.	125												
Sydney, C. B. I.	48	29.92	29.97	+0.02	61.9	−1.4	70.7	53.1	80	42	3.06	−0.56	0.0
Halifax, N. S.	88	29.75	29.85	−.11	63.0	−0.6	69.0	56.1	88	48	4.90	+0.55	0.0
Yarmouth, N. S.	65	29.88	29.95	−.02	59.9	−0.3	67.8	52.0	81	41	1.06	−2.95	0.0
Charlottetown, P. E. I.	38	29.90	29.94	.00	62.7	−1.6	69.4	56.0	83	47	2.79	−0.95	0.0
Chatham, N. B.	28	29.85	29.88	−.05	61.9	−1.3	72.4	51.4	88	40	3.86	−0.18	0.0
Father Point, Que.	20	29.89	29.91	.00	55.5	−0.1	63.6	47.5	77	40	4.44	+1.39	0.0
Quebec, Que.	296	29.66	29.98	+.05	64.0	+0.9	72.3	55.8	83	46	2.24	−1.59	0.0
Montreal, Que.	187	29.76	29.96	+.01	67.1	+0.7	75.2	59.1	86	48	7.68	+4.11	0.0
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.73	29.99	+.03	66.6	+1.8	76.2	57.1	86	46	1.74	−1.29	0.0
Kingston, Ont.	285	29.69	29.99	+.01	67.4	+0.4	74.1	60.7	82	46	4.24	+1.86	0.0
Toronto, Ont.	379	29.58	29.97	−.02	68.5	+2.5	76.4	60.6	86	50	6.12	+3.36	0.0
Cochrane, Ont.	930												
White River, Ont.	1,244	28.68	29.97	+.01	58.1	+1.7	71.8	44.4	90	24	2.06	−1.24	0.0
Port Stanley, Ont.	592												
Southampton, Ont.	656	29.29			63.9	+0.1	72.6	55.2	82	44	4.68	+2.43	0.0
Parry Sound, Ont.	688	29.31	29.99	+.01	64.0	+0.5	73.1	55.0	83	41	2.11	−0.61	0.0
Port Arthur, Ont.	644	29.31	30.02	+.06	62.0	+2.5	70.5	53.2	90	45	2.78	+0.03	0.0
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.19	29.98	+.04	59.8	+0.4	71.0	48.7	83	37	3.72	+1.62	0.0
Le Pas, Man.	860				57.6		70.3	44.9	82	29	0.97		0.0
Qu'Appelle, Sask.	2,115	27.73	29.95	+.02	59.4	−2.1	71.9	46.9	86	35	1.92	+0.28	0.0
Medicine Hat, Alb.	2,144	27.66	29.88	−.04	65.3	−0.4	77.7	52.9	97	43	2.47	+0.80	0.0
Moose Jaw, Sask.	1,759				62.2		75.8	48.6	93	39	3.27		0.0
Swift Current, Sask.	2,392	27.42	29.90	−.03	61.6	−2.4	75.3	47.9	90	39	3.54	+1.63	0.0
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Edmonton, Alb.	2,150	27.68	29.94	+.02	56.8	−2.0	68.6	45.0	80	34	4.84	+2.71	0.0
Prince Albert, Sask.	1,450	28.41	29.97	+.05	58.7	−0.2	70.9	46.5	90	36	2.43	+0.28	0.0
Battleford, Sask.	1,592	28.26	29.98	+0.7	60.9	−1.7	75.0	46.8	93	35	2.43	+0.07	0.0
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.74	29.99	−.02	59.8	+1.1	67.4	52.2	81	50	1.14	+0.54	0.0
Barkerville, B. C.	4,180												
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	29.98	30.14	+.04	79.6	0.0	86.2	72.9	91	62	8.94	+2.86	0.0

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Sydney, C. B. I.	48	29.89	29.94	+.01	62.7	+0.4	72.3	53.1	85	44	4.02	+0.37	0.0
Halifax, N. S.	88	29.71	29.81	−.15	64.0	+0.6	72.4	55.3	85	50	3.65	−0.40	0.0
Yarmouth, N. S.	65	29.84	29.91	−.05	59.7	+0.2	67.5	51.9	79	44	1.49	−2.13	0.0
Charlottetown, P. E. I.	38	29.86	29.90	.00	64.4	+0.3	72.1	56.8	87	50	2.45	−1.04	0.0
Chatham, N. B.	28	29.80	29.83	−.05	64.1	−0.9	76.1	52.2	92	40	2.28	−1.91	0.0
Medicine Hat, Alb.	2,144	27.61	29.81	−.09	73.2	+5.4	88.0	58.5	101	47	0.56	−1.53	0.0
Calgary, Alb.	3,428	26.43	29.93	+.03	64.6	+4.0	80.2	49.0	92	35	1.17	−1.51	0.0
Banff, Alb.	4,521	25.44	29.93	+.03	61.3	+4.7	78.1	44.6	90	32	0.68	−2.56	0.0
Kamloops, B. C.	1,262	28.66	29.92	−.02	72.8	+4.3	87.3	58.4	102	47	0.18	−1.43	0.0
Barkerville, B. C.	4,180	25.70	29.96	+.05	55.7	+0.6	68.4	43.1	83	32	1.47	−1.55	0.0

(Plotted by Wilfred P. Day)

(Plotted by Wilfred P. Day)

Chart II. Tracks of Centers of Cyclones, August, 1926. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)

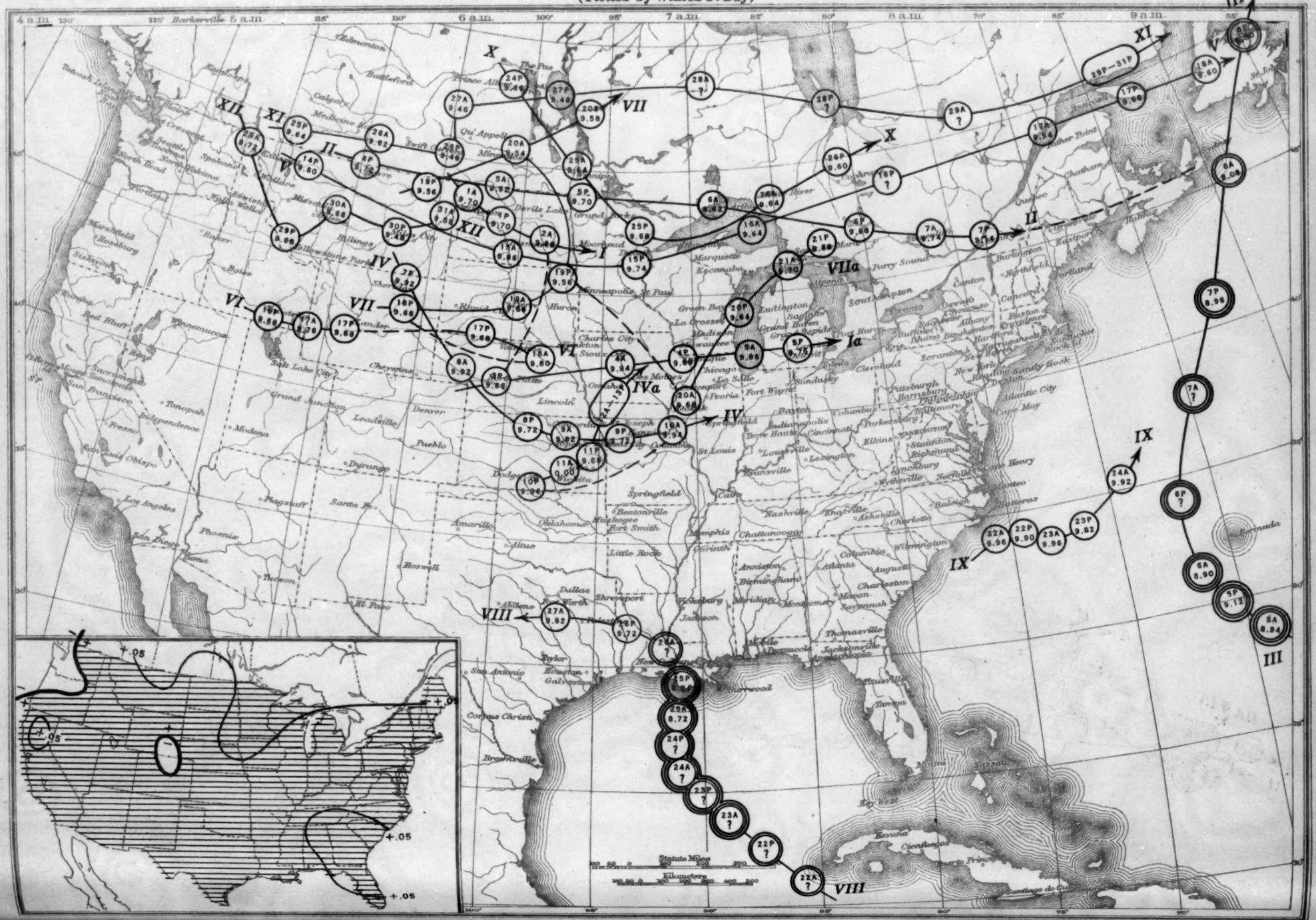


Chart III. Departure (°F.) of the Mean Temperature from the Normal, August, 1926

Chart III. Departure (°F.) of the Mean Temperature from the Normal, August, 1926

Chart IV. Total Precipitation, Inches, August, 1926. (Inset) Departure of Precipitation from Normal

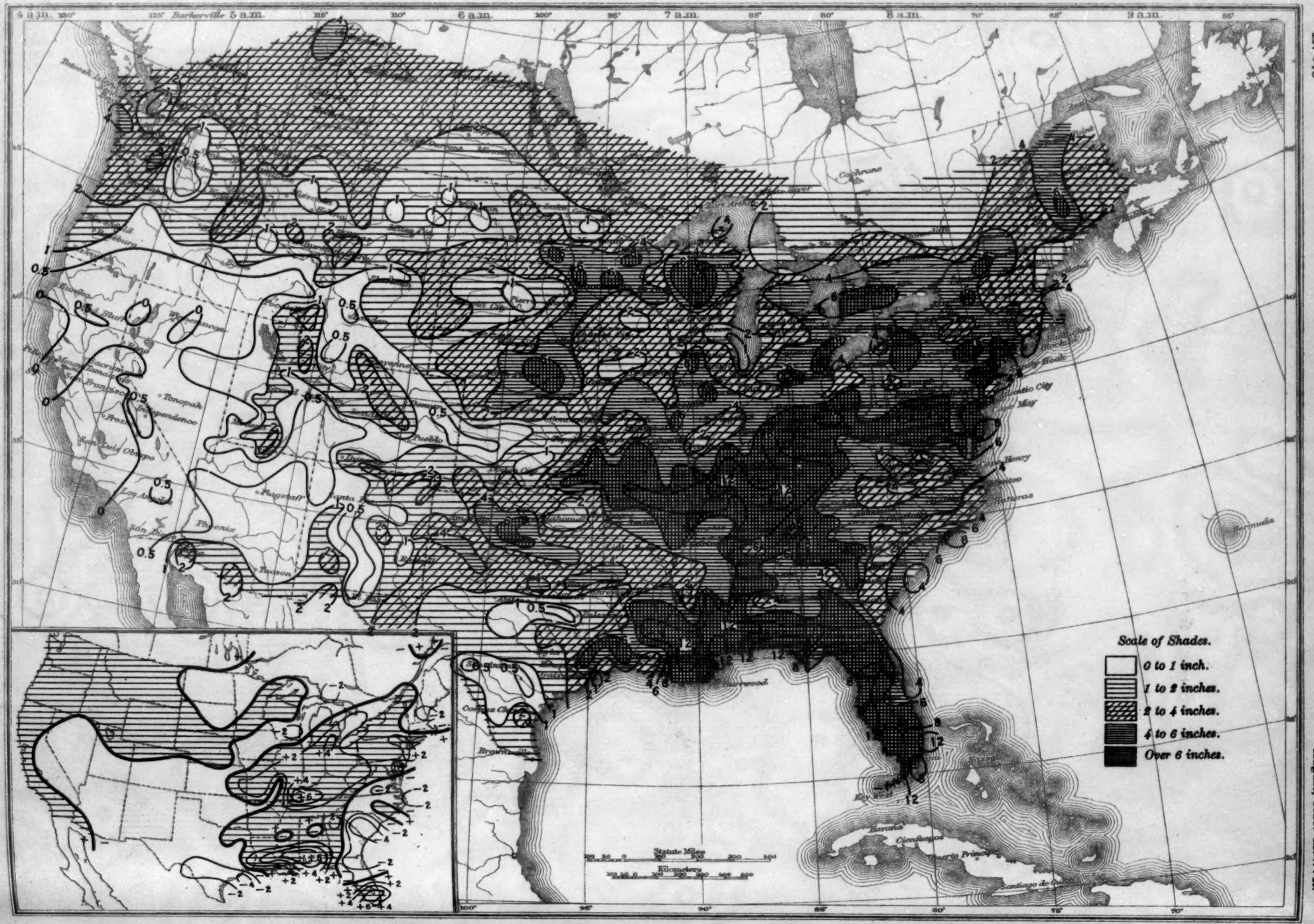


Chart V. Percentage of Clear Sky between Sunrise and Sunset, August, 1926

Chart V. Percentage of Clear Sky between Sunrise and Sunset, August, 1926

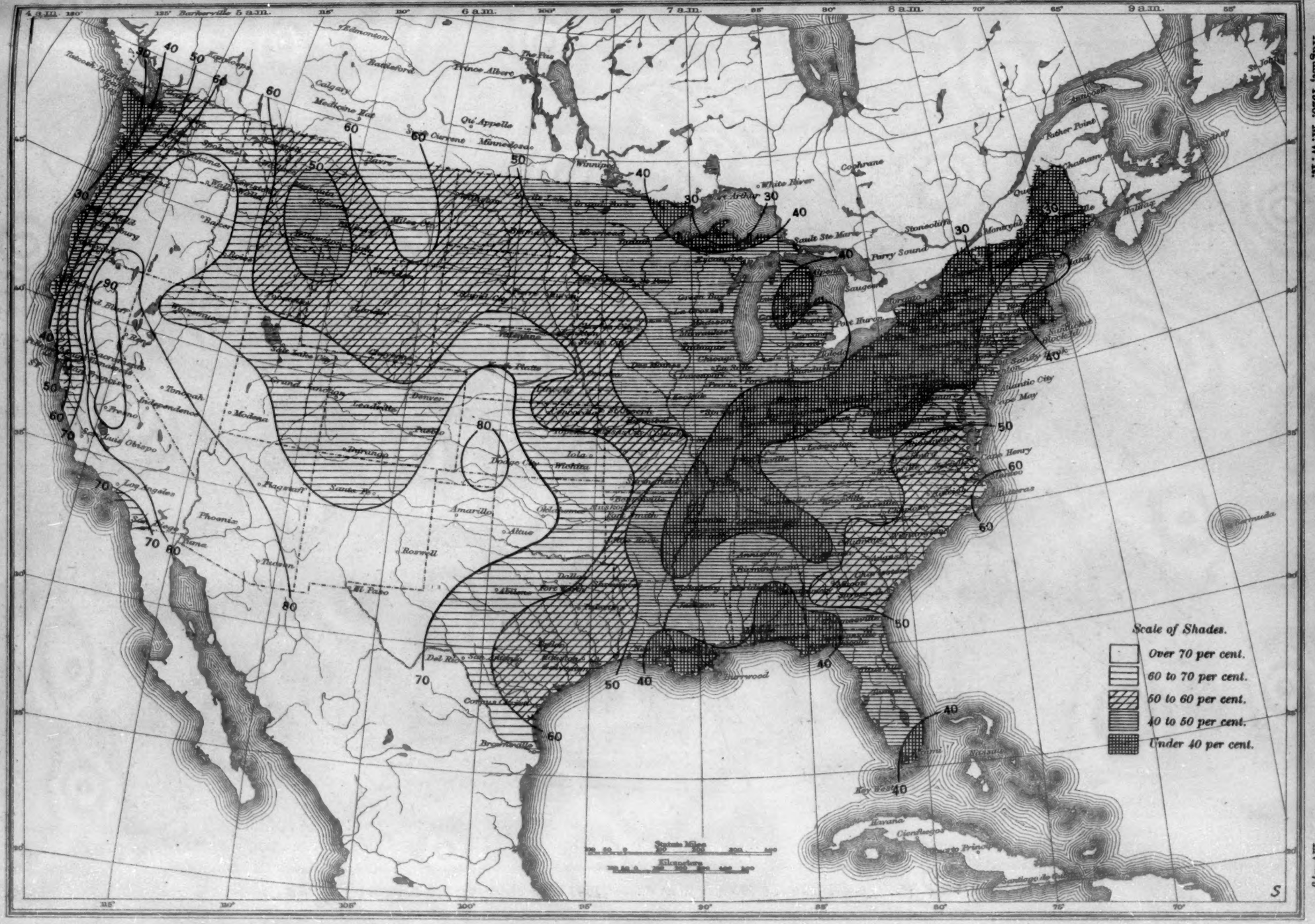


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, August, 1926

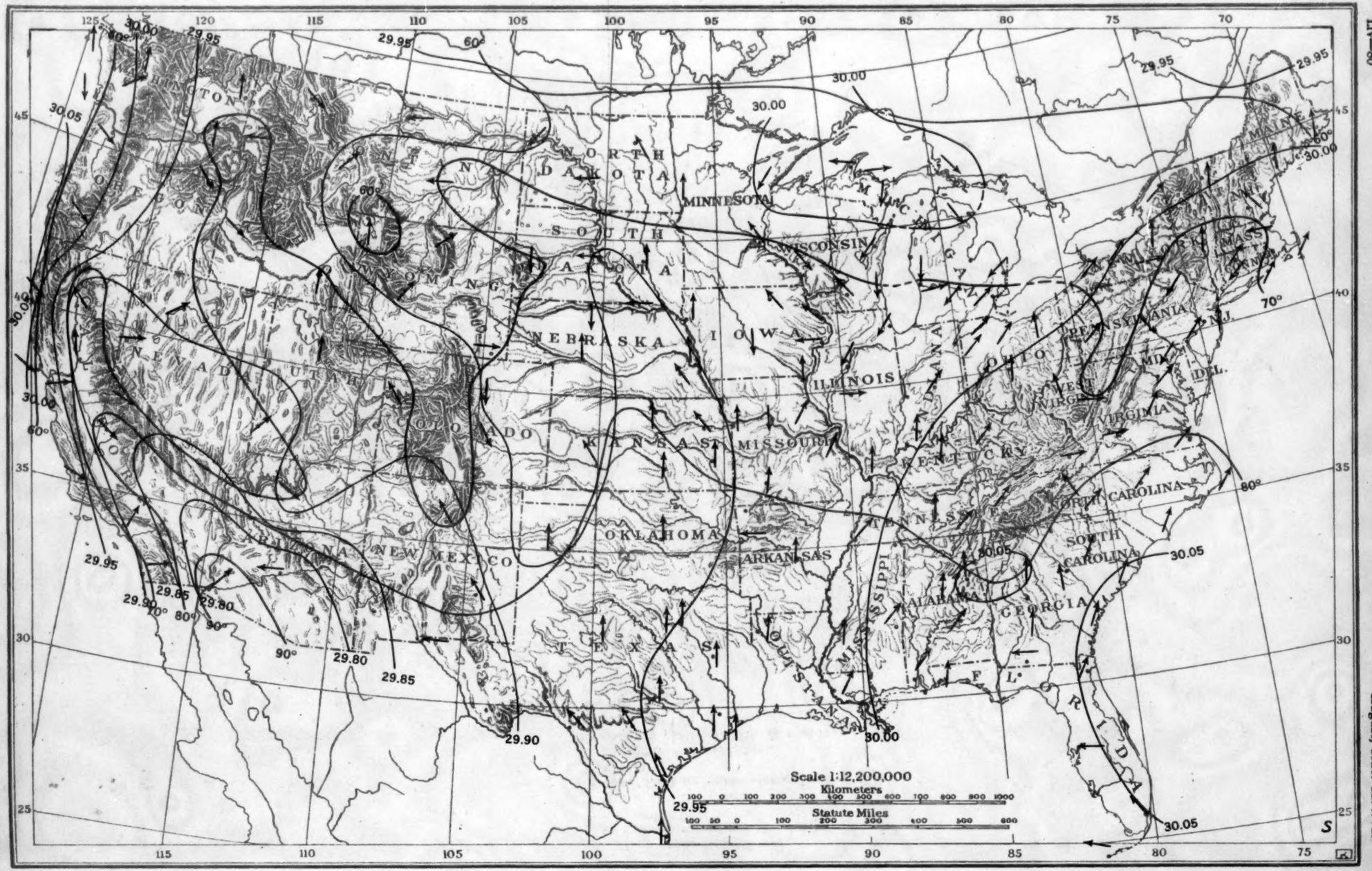


Chart VIII. Weather Map of North Atlantic Ocean, August 5, 1926

(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, August 5, 1926
(Plotted by F. A. Young)

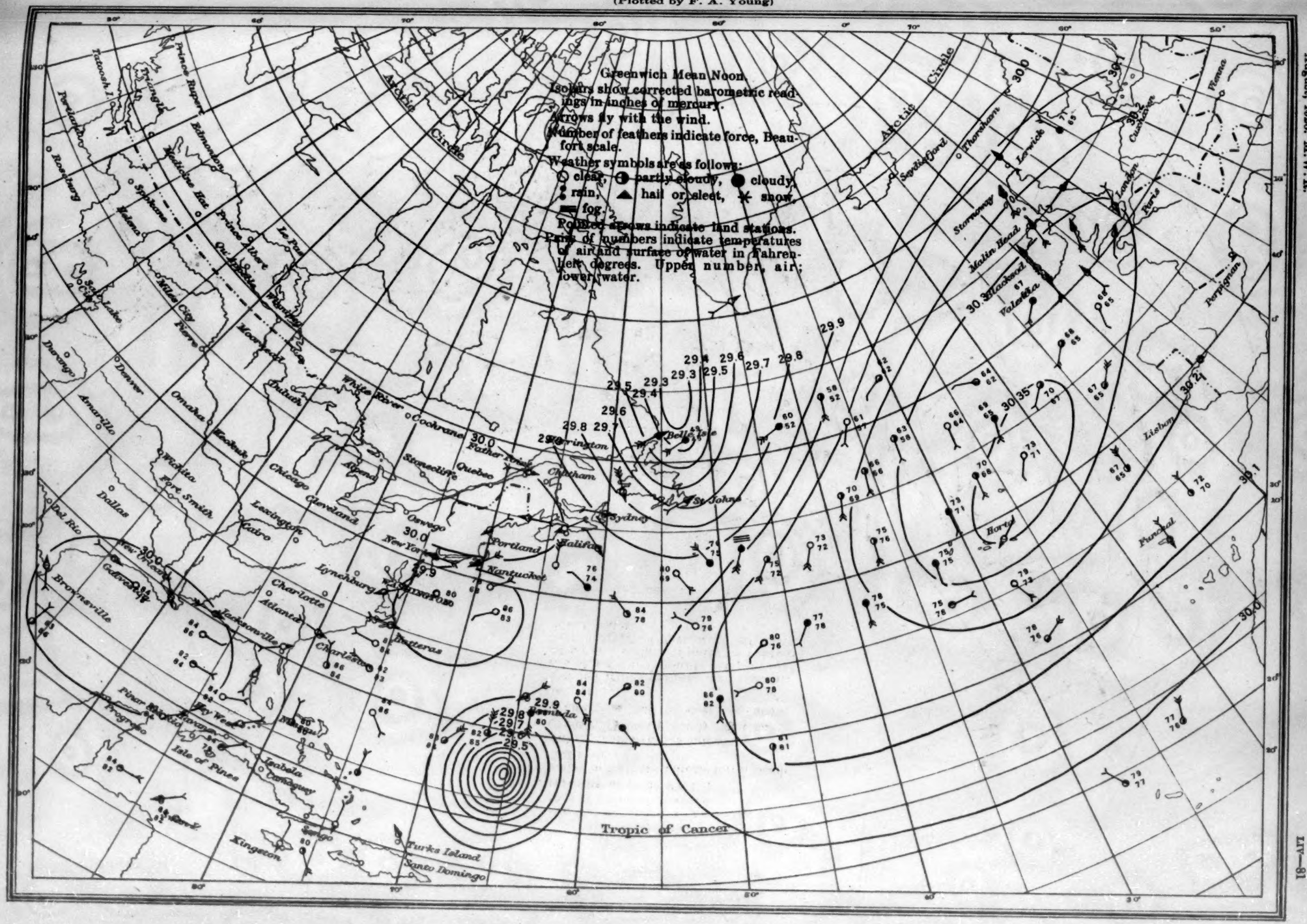

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Dotted arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Tropic of Cancer

Chart IX. Weather Map of North Atlantic Ocean, August 6, 1926

(Plotted by F. A. Young)

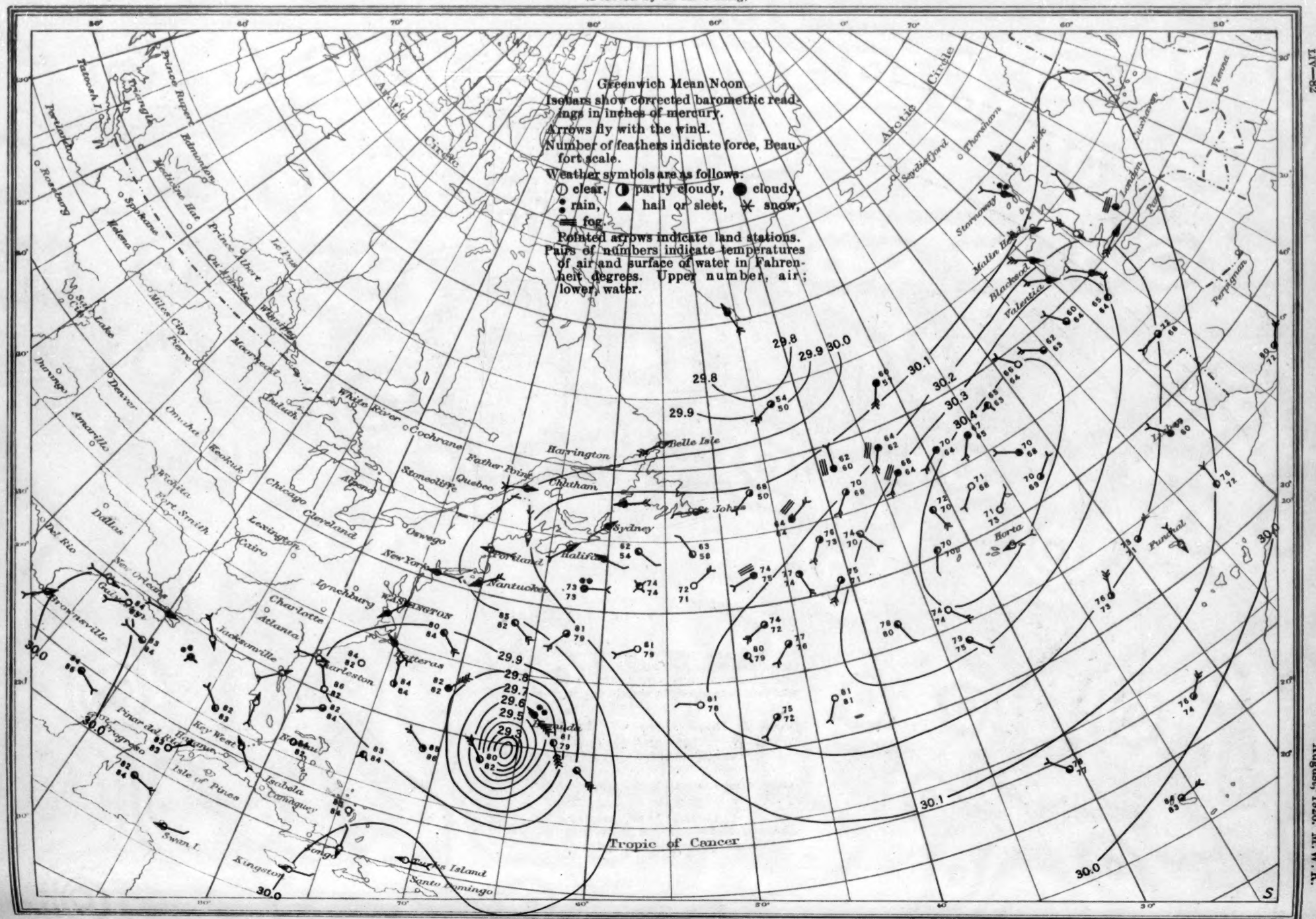


Chart X. Weather Map of North Atlantic Ocean, August 7, 1926
(Plotted by F. A. Young)

Chart X. Weather Map of North Atlantic Ocean, August 7, 1926

(Plotted by F. A. Young)

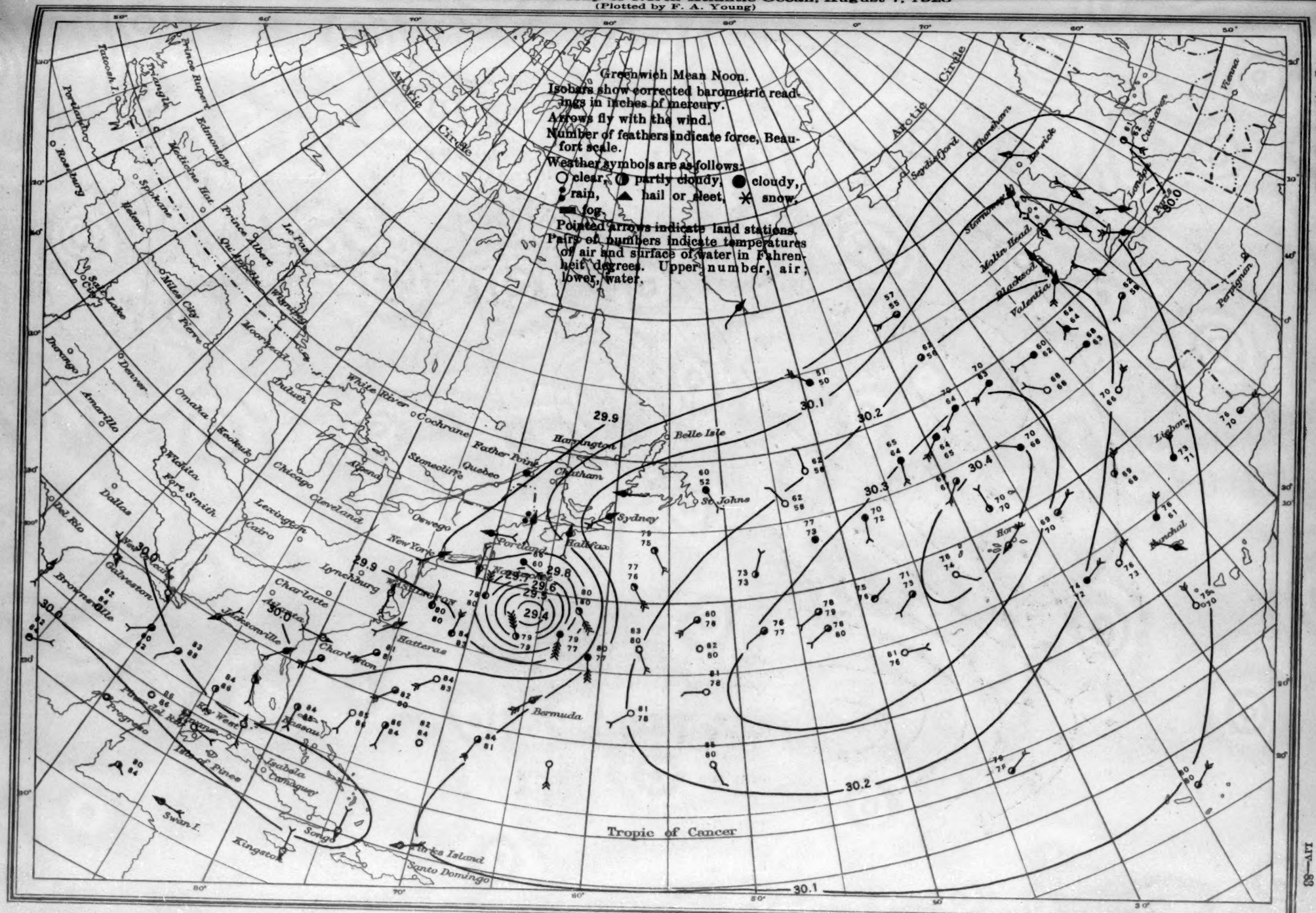
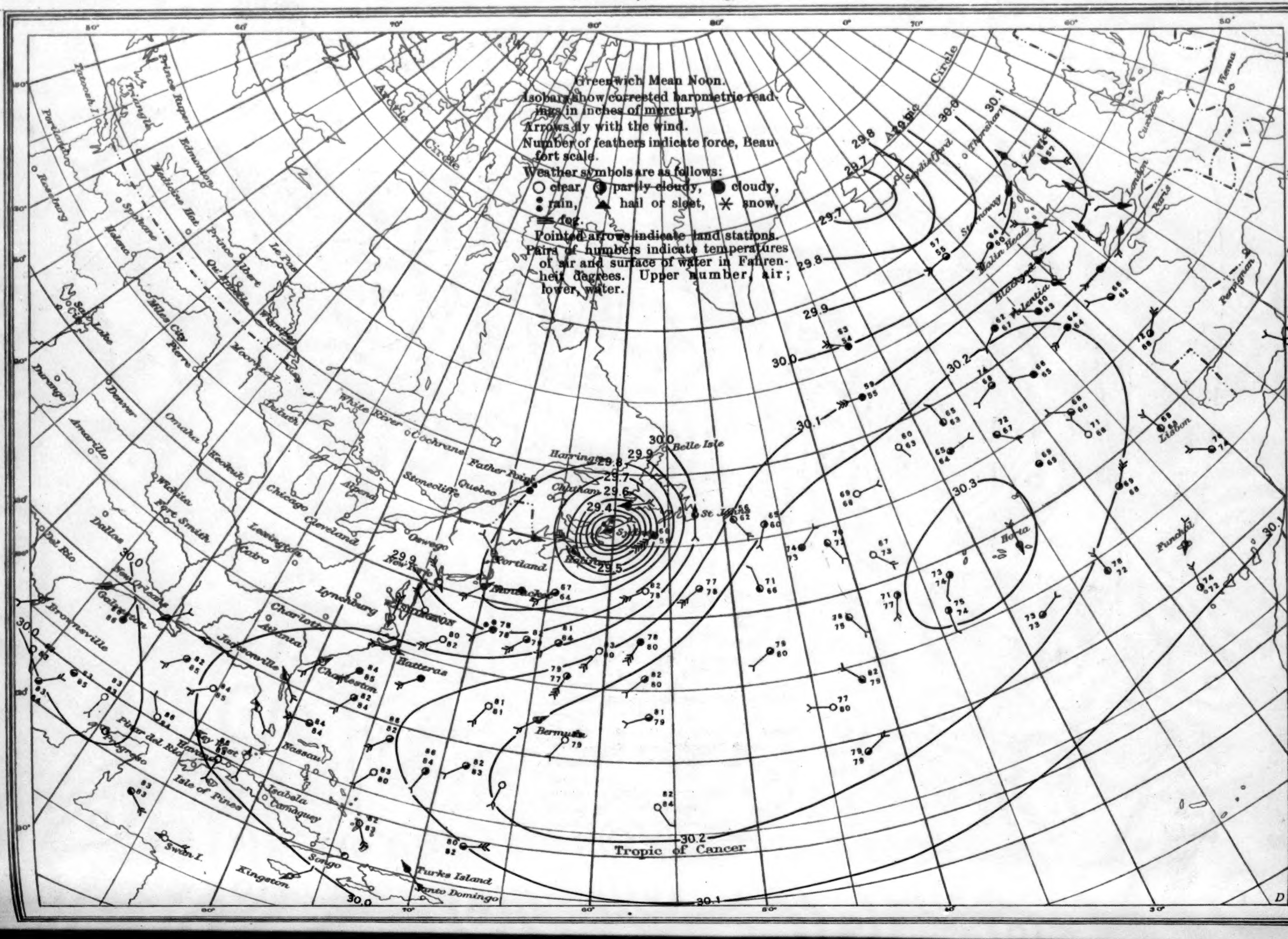


Chart XI. Weather Map of North Atlantic Ocean, August 8, 1926

(Plotted by F. A. Young)